ECOLOGICAL

INFRASTRUCTURE

MAPPING

SOUTHERN ALBERTA

REGION

Government of Alberta ■
Environment

ECOLOGICAL INFRASTRUCTURE MAPPING – SOUTHERN ALBERTA REGION

Prepared by

O2 Planning + Design Inc.

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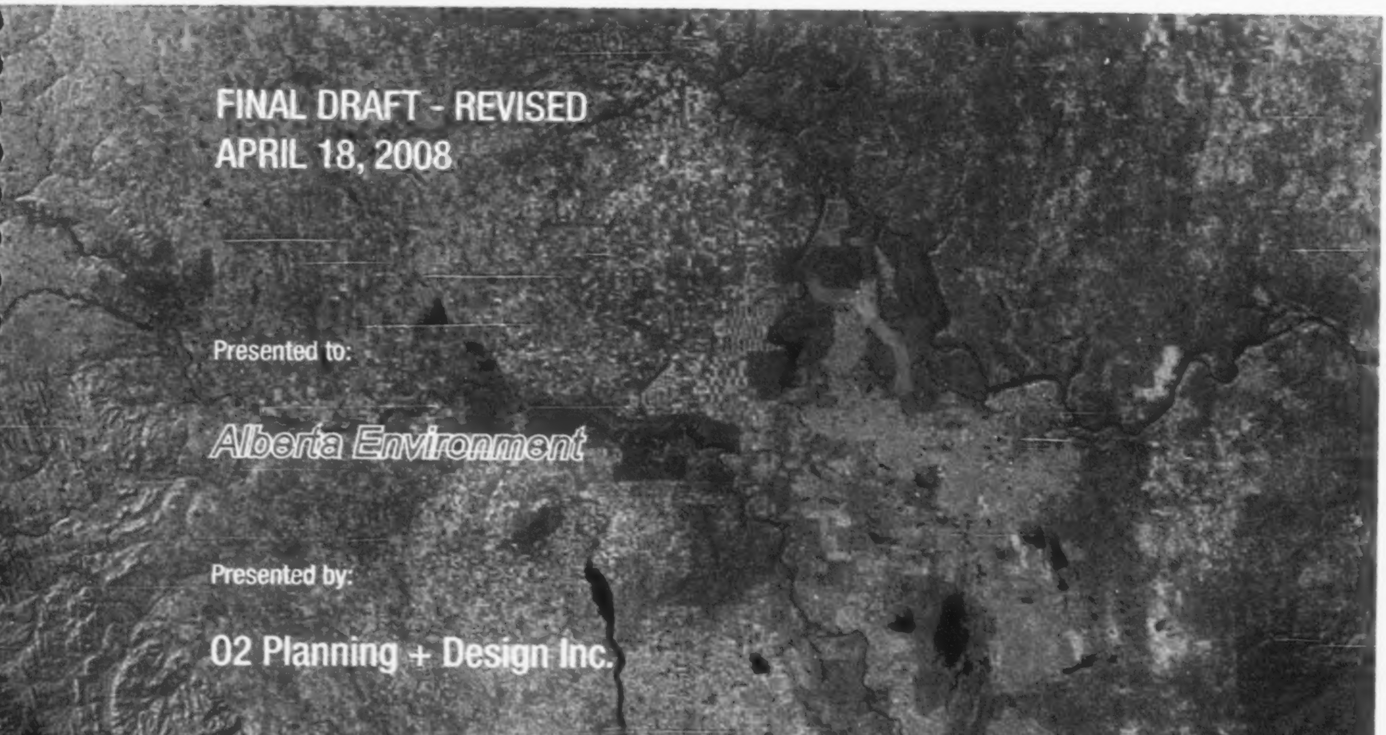

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APRIL 18, 2008

Presented to:

Alberta Environment

Presented by:

O2 Planning + Design Inc.

O2 PLANNING DESIGN

Landscape Architecture, Urban + Environmental Planning

Ecological Infrastructure Mapping – Southern Alberta Region

FINAL DRAFT

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Executive Summary

An assessment of ecosystem goods and services (EGS) in southern Alberta was initiated in 2006 by Alberta Environment. Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life (Daily 1997). The current study builds on the first two project phases by expanding the discussion of landscape patterns required to sustain the provision of ecosystem goods and services based on an identification of ecological infrastructure in the Southern Alberta region. Ecological infrastructure refers to the core features of a network that provides ecosystem services (Tzoulas et al. 2007): in this case, in the Southern Alberta region. At a regional scale, it includes the system of structural and functional terrestrial and aquatic landscape features such as clean water and habitat (Quinn, unpublished work, 2007). Components of ecological infrastructure chosen for mapping in the scope and scale of the current project include:

1. Stream corridors
2. Natural vegetation patches and stepping stones
3. Waterbody complexes
4. Areas of high species richness potential
5. Alluvial soils
6. Unique land cover types or areas

GIS models were created in ArcGIS 9.2 to support the identification and mapping of ecological infrastructure components.

The stream corridors map showed a high density of stream corridors in the forested landscapes to the west and southeast; very few corridors exist in the central Southern Alberta region. The largest patches of natural vegetation over 10 000 ha in size are located in the southeast and northeast. The central part of Southern Alberta has few large patches of natural vegetation, and those that remain in this area will be regionally valuable. The greatest concentration of waterbody complexes is in the northeast portion of Southern Alberta, which has a number of small complexes of standing water. When the top five classes (highest 50%) of species rich areas were selected, grasslands, forests, riparian areas and wetland cover types were picked out. Alluvial soils were found to be concentrated near the base of the Rocky Mountains along the western border of Southern Alberta. Unique land cover types including ridges and low percentage cover types were mapped, but ridges were difficult to analyze at this scale.

A combined map of all ecological infrastructure components was created in which each pixel was assigned a sum value of each ecological infrastructure component it included. The high value of several landscape units to overall regional ecological infrastructure was evident. To identify the areas of coincidence between ecological infrastructure and a spatial representation of ecosystem services in the region, the ecological infrastructure was analyzed against a map representing areas with high importance to the provision of ecosystem services.

The ecological infrastructure was found to encompass 99.6% of all areas identified as high ecosystem service provision. In terms of the condition of ecosystem services, those areas of high service provision that are coincident with ecological infrastructure are most likely to be in good condition through landscape connections and within large natural patches that promote functioning ecological processes. For future application, each component of ecological infrastructure can be mapped on smaller scales, depending on the desired objectives. These processes and models can therefore support informed land use planning in the region.

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List of Abbreviations

AAFC .... Agriculture and Agri-Food Canada
AAFRD .... Alberta Agriculture and Rural Development
AENV .... Alberta Environment
AGRASID .... Agricultural Region of Alberta Soil Inventory Database
ASRD .... Alberta Sustainable Resource Development
AVI .... Alberta Vegetation Inventory
CanSIS .... Canadian Soil Information System
CFS .... Canadian Forest Service
DEM .... Digital Elevation Model
EGS .... Ecosystem Goods and Services
ETM .... Enhanced Thematic Mapper
GOA .... Government of Alberta
GIS .... Geographic Information Systems
HSI .... Habitat Suitability Index
LU .... Landscape Unit
NAESI .... National Agri-Environmental Standards Initiative
NAHARP .... National Agri-Environmental Health Analysis and Reporting Program
NSR .... Alberta Natural Subregions
SAL .... Southern Alberta Landscapes
TPI .... Topographic Position Index

1.0 Introduction

An assessment of ecosystem goods and services (EGS) in southern Alberta was initiated in 2006 by Alberta Environment. The EGS assessment was intended to provide important background information in support of developing the Southern Alberta Landscapes (SAL) regional strategy and to identify areas of further investigation and study regarding the importance of EGS in southern Alberta. The project was conceived as a two-phase effort: Phase 1 involved the completion of a survey of ecosystem goods and services initiatives in southern Alberta and elsewhere (*Ecosystem Goods and Services Assessment – Southern Alberta, Phase 1 Report: Key Actors and Initiatives*, Integrated Environments (2006) Ltd. and O2 Planning + Design. Inc. 2007a) while the second phase was a subjective, qualitative evaluation of the relative importance of the ecosystem services to society in southern Alberta (*Ecosystem Goods and Services Assessment – Southern Alberta, Phase 2 Report: Conceptual Linkages and Initial Assessment*, Integrated Environments (2006) Ltd. and O2 Planning + Design. Inc. 2007b). The geographical scope of the EGS assessment includes the southern portion of the province of Alberta, referred to as 'Southern Alberta' in the current document (Figure 1.1).

Figure 1.1. The EGS assessment area.

Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life

(Daily 1997). These services provide us with valuable economic goods, are essential for the ongoing maintenance of critical life-support systems and confer a wide range of highly valued non-market benefits. The purpose of the Phase 2 EGS study was to identify which ecosystem goods and services are important to southern Alberta and how they help sustain the region's vibrant economy and quality of life. The objectives of the Phase 2 EGS Assessment were to: a) inform people about ecosystem goods and services and how they are important to economic production in southern Alberta, b) help people understand how land use decisions and human activities impact these services, c) determine what landscape patterns are required to sustain the ongoing delivery of ecosystem goods and services and, d) undertake a gap analysis to identify directions for further study and investigation.

The current study builds on the first two project phases by expanding the discussion of landscape patterns required to sustain the provision of ecosystem goods and services based on an identification of ecological infrastructure in the Southern Alberta region.

Ecological infrastructure refers to the core features of a network that provides ecosystem services (Tzoulas et al. 2007): in this case, in Southern Alberta. At a regional scale, it includes the system of structural and functional terrestrial and aquatic landscape features such as clean water and habitat (Quinn, unpublished work, 2007). Large patches of natural vegetation and wide regional corridors are important components of regional-scale ecological infrastructure.

In the current study, Geographic Information Systems (GIS) models were constructed and applied to the southern Alberta region in order to identify areas of ecological infrastructure.

1.1 Structure of Report

Section 1.0 presents an introduction to the project, including the rationale for mapping ecological infrastructure in Southern Alberta, the relationship to ecosystem goods and services and an overview of the study methods.

Section 2.0 discusses the relevant components of ecological infrastructure for this scale and region.

Section 3.0 describes the conceptual division of Southern Alberta into Landscape Units (LUs) in order to better evaluate ecological infrastructure at a regional scale, where many different landscape patterns are present.

Sections 4.0 present the tools and analyses used to identify each component of ecological infrastructure chosen for this study and show the results.

Section 5.0 makes conclusions regarding the ecological infrastructure analysis and discusses implications.

Section 6.0 analyses the results in terms of their coincidence with ecosystem goods and services and potential implications.

Chapter 7.0 concludes with recommendations for future work and application of the tools and models for different scales of analysis.

1.2 Rationale

Identifying ecological infrastructure in a region can support several objectives:

- To permit the functioning of natural ecological process in the provision of ecosystem goods and services;
- To support biodiversity in the region, maintain wildlife habitat and enable movement of populations;
- To maintain clean water at the source and as it moves through the region's landscapes; and,
- To protect the integrity of the landscapes across the region.

A major function of well-managed ecological infrastructure is maintaining ecosystem services and building resilience in the landscape (Colding 2007, Tzoulas et al. 2007). Ecosystem services have been defined as the delivery, provision, protection or maintenance of goods and services that humans obtain from ecosystem functions (Bolund and Hunhammar 1999, de Groot et al. 2002, Millenium Assessment 2003 in Tzoulas 2007). A functional ecological infrastructure across the region can aid in biodiversity conservation and water quality protection and in sequestering carbon against increased climate change. The added resiliency in the landscape would also help buffer against climate change-induced impacts on the area. When properly and proactively planned, developed and maintained, ecological infrastructure provides a solid framework for economic growth and environmental conservation (Schrijnen 2000, Walmsley 2006, Tzoulas et al. 2007).

Spatial identification of critical ecological infrastructure in the region can aid in macro-scale assessment of asset (land cover type) condition in providing ecosystem goods and services. As such, this project addresses one of the research gaps (Gap #4) identified in the *Ecosystem Goods and Services Assessment – Southern Alberta Phase 2 Report* (Integrated Environments (2006) Ltd. and O2 Planning + Design Inc. 2007b). In order to assess the condition of a natural asset, it was recommended that two scales of analysis be conducted. The current work addresses the regional-scale evaluation of asset condition by looking at asset composition, configuration and connectivity.

1.3 Methods

In order to map ecological infrastructure in Southern Alberta, the study area was first subdivided into landscape units (LUs) based on common spatial pattern, configuration and ecology to create smaller units of analysis (Section 3.0).

GIS models were created in ArcGIS 9.2 to support the identification and mapping of ecological infrastructure components (Section 4.0). The project input datasets included the integrated southern Alberta inventories land cover, Alberta base hydrographic features data, Alberta AGRASID and Canada Soil Information System soils data and digital elevation model (DEM) data. Datasets and general processing are detailed in Appendix A.

Results from the ecological infrastructure mapping were compared with maps of ecosystem goods and services prepared from the *Phase 2* assessment (Integrated

Environments (2006) Ltd. and O2 Planning + Design Inc. 2007b) to produce a coincidence of analysis map.

The report was then written to describe the methodology used to develop the geospatial models as well as the supporting rationale for the identification of landscape units and ecological infrastructure components.

1.4 Scope

The scope of this phase of the project is to conduct a regional-scale assessment of ecological infrastructure in Southern Alberta. While this assessment covers many components, some components of ecological infrastructure, while important, are more appropriate for evaluation at finer scales of analysis or for regions with different physical geography and ecological characteristics.

Appendix B relates the relationship of identified ecological infrastructure components to recommended resource survey features (Bastedo et al. 1986, Cook et al. 1993). Those components to be analyzed during this phase are shown and recommendations are given where future analyses may be appropriate.

2.0 Ecological Infrastructure Components

The region is composed of both natural and anthropogenic assets, or land cover types. The area of each asset can vary, altering the landscape composition. Natural assets refer to the stock of natural resources from which many goods are produced in Southern Alberta (Integrated Environments (2006) Ltd. and O2 Planning + Design Inc. 2007b). Anthropogenic assets are defined as man-made assets, the footprint of which now occupies areas of former natural assets (Integrated Environments (2006) Ltd. and O2 Planning + Design Inc. 2007b). In Southern Alberta, natural and anthropogenic assets are described in Table 2.1.

Table 2.1. Natural and anthropogenic assets in Southern Alberta.

Natural Assets	
Native Prairie	
Needle and thread dry mixed grass	western porcupine grass, needle and thread grass, western wheat grass, blue grama grass, June grass, plains wheat grass, pasture sagewort, silver sagebrush
Northern wheat dry mixed grass	needle and thread grass, June grass, northern wheatgrass, western wheatgrass, Idaho fescue, Kentucky bluegrass, snowberry, sagebrush
Needle and thread sand grass – dry mixed grass	pasture sagewort, prickly pear cactus, western wheatgrass, sandberg bluegrass, blue grama grass, June grass, green needle grass, foxtail barley
Mixed grass	rough fescue, porcupine grass, June grass, sand grass, western wheatgrass, silver sagebrush
Fescue grasslands	western wheatgrass, rough fescue, Parry's oat grass, needle and thread grass, silver sagebrush, June grass, western porcupine grass, Idaho fescue
Rocky Mountain and parkland fescue	willow, rough fescue, Parry's oat grass, sand grass, Idaho fescue
Prairie treed and riparian cottonwood	narrow-leaved cottonwood, green ash, saskatoon, western clematis, chokecherry, poison ivy, skunkbrush, golden currant, reed canary grass, bluegrass, slender wheatgrass, perennial ragweed, Indian hemp, prairie sagewort, showy milkweed
Prairie shrub	silver sagebrush, western porcupine grass, needle and thread grass, snowberry, green needle grass, juniper, sand grass, rough fescue, bunchgrass fescue, western wheatgrass
Badlands and thin breaks	northern wheatgrass, June grass, sedge, thread-leaved sedge, moss phlox

Forest	
Forest shrub	common wild rose, thorny buffaloberry, red-osier dogwood
Hardwood forest	trembling aspen, balsam poplar
Mixed wood forest	aspen, balsam poplar, white spruce, balsam fir
Spruce and fir forest	white spruce, Engelmann spruce, Douglas fir
Pine forest	lodgepole pine, jack pine, limber pine
Aquatic	
Lentic (standing)	lakes, potholes, open marshes, ponds
Lotic (flowing)	perennial streams, intermittent channels
Wetlands (forest and prairie)	bogs, fens, marshes, sloughs, wet meadows, riparian zones
Geologic	
Bare soil and rock	mountain tops, scree slopes
Ice	glaciers
Anthropogenic Assets	
Agricultural	
Cereal crops	barley, buckwheat, canary seed, grain corn, oats, millet, rye, wheat
Oilseeds and legumes	canola, flax, mustard, safflower, sunflower, chickpeas, dry beans, dry peas, lentils
Specialty crops	catnip, mint, onions, soybeans, sugar beets, sweet corn, turf sod, potatoes
Forage crops	alfalfa, oats silage, silage corn, sweet clover, milk-vetch, white clover
Tame pasture	brome grass, creeping red fescue, crested wheatgrass, meadow bromegrass, meadow fescue, crown vetch
Other Anthropogenic	
Roads and rails	highways, gravel roads, forestry and access roads, railroads
Rural / agricultural residential	houses, yards and outbuildings

Cities and towns	cities, towns, villages, summer villages
Well sites	active oil wells
Pipelines, transmission and seismic lines	pipelines (on native prairie), seismic lines (in forested areas), transmission lines
Feedlots	confined feeding operations
Recreation	campgrounds, ski hills
Mines and pits	coal mines, limestone quarries, gravel pits, burrow pits
Industrial sites	potato processing plants, saw mills
Reservoirs	anthropogenic lentic water bodies
Canals	major anthropogenic canals, aqueducts and ditches

Ecological infrastructure consists of natural assets that should ideally take the form of a patch and corridor spatial configuration that includes corridors and stepping stones (individual habitat patches) to counteract effects of fragmentation (Ahern 1995, Bryant 2006). According to Forman (1995) key components of an ecological infrastructure include:

- strategic points;
- aggregate-with-outliers pattern;
- indispensable patterns;
    - large patches of natural vegetation;
    - well-vegetated riparian corridors;
    - connectivity through corridors or stepping stones; and,
    - heterogeneous remnants of natural patches derived from a large patch nearby (Forman 1995, Pirnat 2000).

Strategic points are locations on the landscape that have important contents and source effects, such as large natural areas or unusual features; are especially sensitive to change; or are centres of flows or movement such as stream corridors and steep slopes (Forman 1995).

The aggregate-with-outliers pattern refers to a landscape pattern in which land uses are aggregated yet corridors and small patches of nature are scattered throughout developed areas, and outliers of human activity are positioned along major natural boundaries (Forman 1995). This model has a range of development and ecological benefits, including providing a wide range of settings for development and nature; efficiency of movement for humans and ecological processes; maintenance of large patches and the ecosystem services they provide; and variance in grain size providing visual diversity.

The current project focuses on indispensable landscape patterns, which, at a broad scale, encompass the ideas of strategic points and aggregate-with-outliers

patterns. Indispensable landscape patterns focus on configuration and connectivity of natural assets.

Landscape Configuration and Connectivity

Landscape configuration refers to the spatial arrangement of land cover types, including patch size, isolation and shape. In terms of regional biodiversity, the point at which spatial planning is most important is when 10-40% of the natural vegetation has been removed (Forman and Collinge 1997, Kennedy et al. 2003).

Connectivity can be defined as the "degree to which habitat for a species is continuous or traversable across a spatial extent" (Andersson 2006). Connectivity is also important for many ecological processes such as disturbance regulation, biological control and nutrient cycling, among others. Structural connectivity and functional connectivity are both elements of this definition. Connectivity is best described in ecological terms by multivariate descriptions including: area, number of patches, patch extent, level of aggregation, and perimeter area fractal dimension (Bierwagen 2005).

Connectivity between large patches can be maintained through corridors and stepping stones. A corridor is defined as a strip of land that differs in composition from the surrounding matrix (Fleury and Brown 1997), while a stepping stone is a habitat patch where an animal stops while moving along a heterogeneous route (Forman 1995). Having appropriate corridors and stepping stones for wildlife can alleviate problems of habitat fragmentation in the landscape by connecting patches too small to contain viable populations over the long-term and allowing for gene flow between populations.

Each large patch of natural vegetation should have at least two connections to other patches in order to include diverse habitat types within the connected areas and to minimize potential barriers to movement or unexpected events that could disrupt dispersal (Fleury and Brown 1997).

Components of ecological infrastructure chosen for mapping in the scope and scale of the current project include:

1. Stream corridors
2. Natural vegetation patches and stepping stones
3. Waterbody complexes
4. Areas of high species richness potential
5. Alluvial soils
6. Unique land cover types or areas

These components of ecological infrastructure have precedence in previous biodiversity planning studies for the mixed-grass prairie ecoregion (*National Agri-Environmental Standards Initiative (NAESI) – Development of Habitat-Based Biodiversity Standards*; O2 Planning + Design Inc. et al. 2007) and regional land use planning projects (*Calgary Regional Partnership (CRP) Land Use Plan*; O2 Planning + Design Inc., in progress).

3.0 Landscape Units

There are several ways of dividing a region into appropriate units for management that do not necessarily follow administrative boundaries. One common management division is the watershed or subbasin: the area drained by a river or stream and its tributaries (Forman and Godron 1986). This is the unit of choice for many resource planning exercises and environmental protection schemes, and is useful for many applications particularly when fluvial processes are the focus of interest.

Another basis for division is the selection of *landscapes*. A landscape is defined as a "heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout" (Forman and Godron 1986). A landscape generally contains more than one watershed, and its boundary may or may not correspond to watershed boundaries (Forman and Godron 1986). Landscapes are generally defined on the scale of kilometers. Landscapes reflect both the human use of the area as well as underlying physiographic conditions and ecological potential.

The use of landscapes as a basis for divisional units in this project is to reflect the differences in land use and ecology in the regional ecological infrastructure. A rare cover type in one LU, for example, may be quite common in several others and would not be identified on a large-scale regional analysis alone. Another practical reason for using LUs to subdivide the region is to reduce the considerable computation required for many of these analyses.

With the intention to subdivide the region into 10-30 distinct units, several layers of ecological data were considered. Natural Subregions (NSRs) were considered but these are partially based on elevation, which creates many small island polygons across the region. The Canadian Soil Information System (CanSIS) soil polygons are the basis of the Canadian ecological hierarchy (from coarse to fine scale):

- ecozones
- ecoprovinces
- ecoregions
- ecodistricts

Soil polygons and ecodistricts are too fine in scale for the current project and would create too many polygons. To get around this problem, the next highest category, ecoregions, was used and crossed with watershed basins to provide relevant units for both landscape and watershed analysis. The result is 26 distinct landscape units based on soils and hydrology (Figure 3.1).

Use of this landscape unit framework is consistent across multiple scales, so that broad-scale analyses (such as the current study) could delineate units using watershed basins and ecoregions while fine-scale analyses could use watershed sub-basins and ecodistricts. This nested hierarchy has the potential to scale down in future applications.

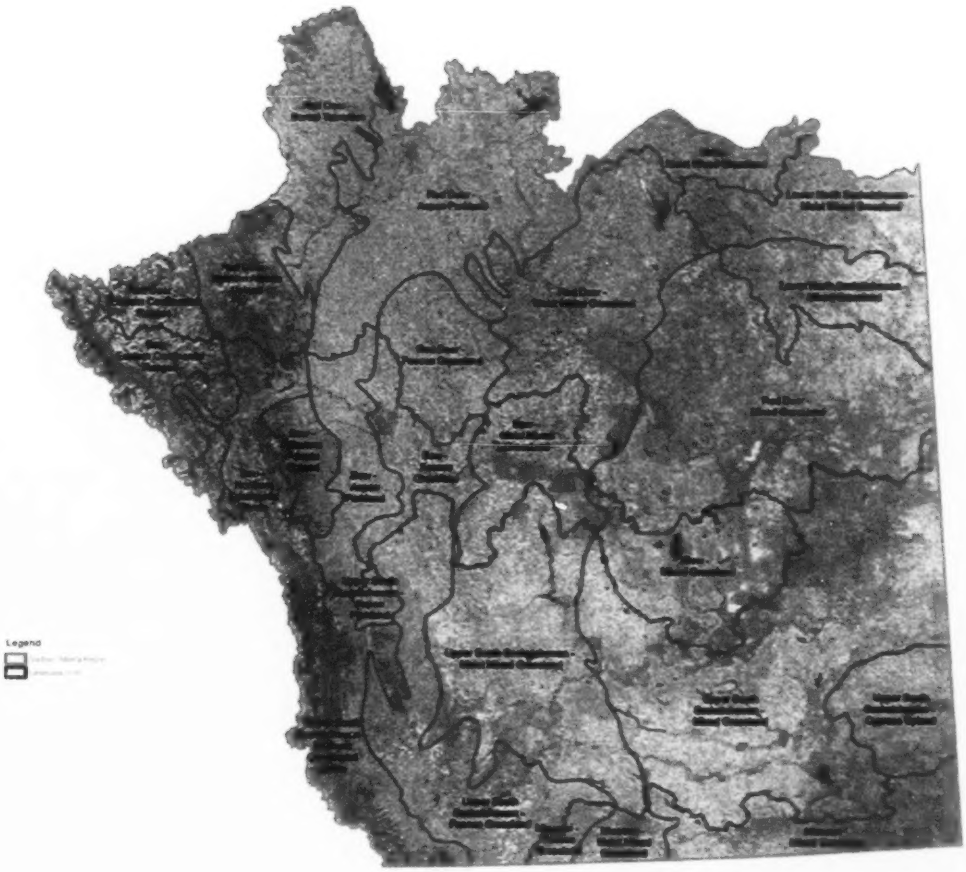

Figure 3.1. Landscape Units.

4.0 Mapping Ecological Infrastructure

Tools and models were developed to spatially identify the regional components of ecological infrastructure identified in Section 2.0. The tools and models that were developed for this project accompany this report in a set of DVDs containing all input datsets, output datasets, ArcGIS 9.2 models and ArcGIS 9.2 map templates (MXDs). If the project DVDs are extracted to the root of a user's C drive, the models can be run and any links within this document will work.

4.1 Stream Corridors

Stream corridors were based on the identification of lotic watercourses from the integrated southern Alberta inventories. Lotic relates to actively moving water, as opposed to still waters which are analyzed in Section 4.3.

Depending on management objectives (e.g., water quality protection, maintenance of ecological processes, wildlife habitat), the appropriate width of a stream buffer can vary. Water quality protection buffers are typically much narrower than riparian buffers for wildlife habitat. A riparian buffer is defined as an area of land and vegetation adjacent to a watercourse or waterbody, often consisting of perennial vegetation, that receives different management from the surrounding landscape (Dosskey 1998, WDNR 2006).

Mid-order (third- and fourth-order) streams have high biodiversity and are responsible for conserving the water quality and the organisms of the lower-order streams flowing into it, and are often given the greatest attention when it comes to riparian buffers (Spackman and Hughes 1995). While important, first- to third-order streams often have sharper gradients and can be susceptible to high erosion and sedimentation without adequate vegetation cover, which leads to habitat degradation (EC 2004). These streams are also important as they carry runoff into the larger streams and watercourses, thus having a large impact on water quality in the higher order rivers downstream (WDNR 2006). Water quality protection is critical in these first- to third-order streams.

Castelle et al. (1994) recommended a 15-30 m buffer width for water quality considerations, while Environment Canada (EC 2004) recommended a 30 m minimum buffer along at least seventy-five percent of a stream's length. In Manitoba, a healthy riparian buffer is defined as a 20 m strip of natural vegetation on each side of the annual high water mark, with cultivation limited to at least 10 m from the edge of the bank (Manitoba Conservation 1995).

Recommended buffers are widened when the riparian function as wildlife corridor and habitat is taken into account. Adequate stream buffer widths varied from 10-30 m above the annual high-water mark for 90% of vascular plants and from 75-175 m for 90% of avian species (Spackman and Hughes 1995). While the authors suggested that widths of stream buffers depend highly on the individual characteristics of the stream and that other variables such as elevation and slope of the streambank may be better habitat width predictors, they did recommend natural riparian corridors of >150 m for maintaining avian species diversity. Kennedy et al.'s (2003) literature review determined that 75% of

riparian buffer studies reviewed recommended a 100 m minimum riparian width to conserve water quality and wildlife habitat.

A buffer of 100 m in width should encompass both the riparian area and upland corridor adjacent to most streams. Riparian areas are the streamside environments that are influenced by hydrologic processes creating a distinct vegetation community. These areas are especially high in biodiversity due to the diversity of local habitat types, the availability of both aquatic and terrestrial resources, and the higher primary productivity and greater moisture availability (Bennett 1999, Chapman and Ribic 2002, Peak and Thompson 2006).

A typical stream corridor cross-section showing ecological functions is given in Figure 4.1.

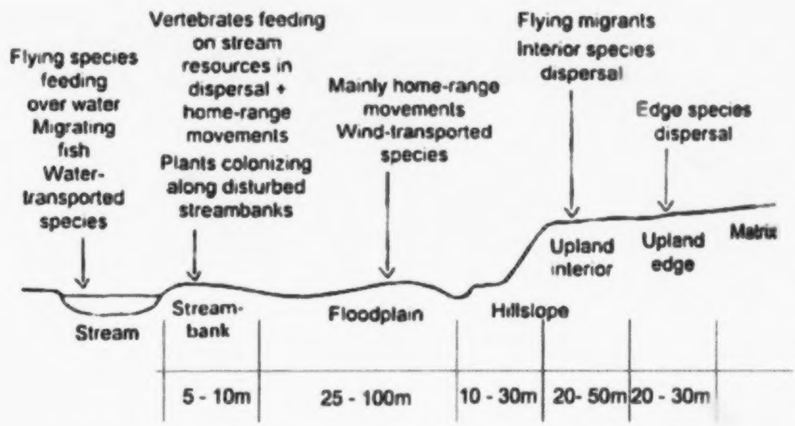

Figure 4.1. Stream corridor dispersal functions and approximate widths (adapted from Forman 1995).

On a regional scale, where a corridor is intended to be used by a variety of species and persist over a long period of time, the corridor should be on the scale of kilometres in width. Continuous corridors across landscapes offer:

- effective linkages for communities and ecological processes (Bennett 1999);
- protection of habitat across the aquatic / terrestrial interface for a range of species;
- maintenance / improvement of water quality by providing sediment control and absorbing and filtering dissolved substances (Castelle et al. 1994, Dramstad et al. 1996, Kennedy et al. 2003);
- maintenance of water quality through temperature and oxygen control (Castelle et al. 1994, Kennedy et al. 2003); and,
- flood control functions.

4.1.1 Data and Assumptions

Lotic areas were selected from forest and grassland portions of the integrated southern Alberta inventories, excluding piped canals. Lotic areas from the forest portion were merged with the lotic areas from the grassland portion to create a dataset that covered the entire Southern Alberta region. The integrated Southern Alberta inventories hydrology was then buffered by 100 m on each side to identify stream corridors. The accuracy of the output stream corridors is the same as the accuracy of the integrated southern Alberta inventories data.

Some anomalous buffers were created in the forest portion, possibly due to the input polygons having complex geometry. An attempt was made to use the line boundaries of the polygons but selecting from the line features of the coverage could not be performed due to the line features lack of attribute data. Alternatively, an attempt was made to convert the selected polygons to lines but the attempt crashed ArcGIS on each of five attempts. It may be possible to run the model on a smaller subset of the forested portion of the integrated southern Alberta inventories data.

4.1.2 Model

A flow diagram of the ArcGIS 9.2 model is presented in Appendix C. The model is located in an ArcGIS Toolbox in the following location:

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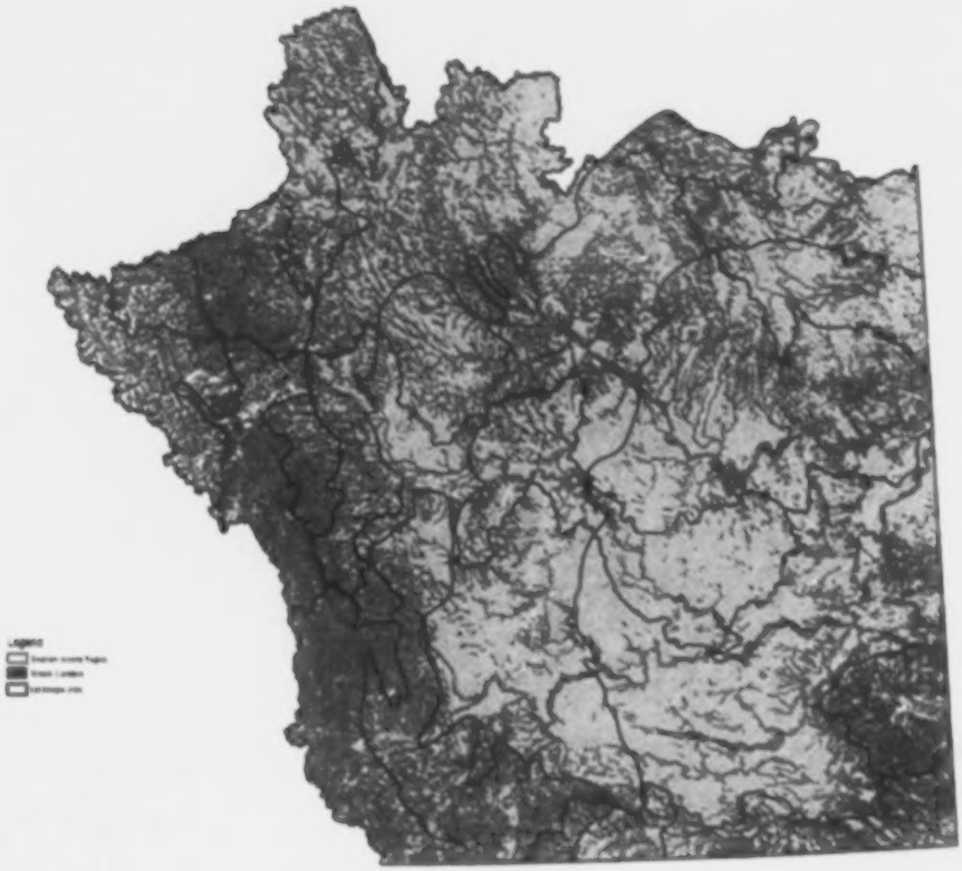
The results of the model over the entire Southern Alberta region are presented in Figure 4.2.

Figure 4.2. Stream corridors in Southern Alberta.



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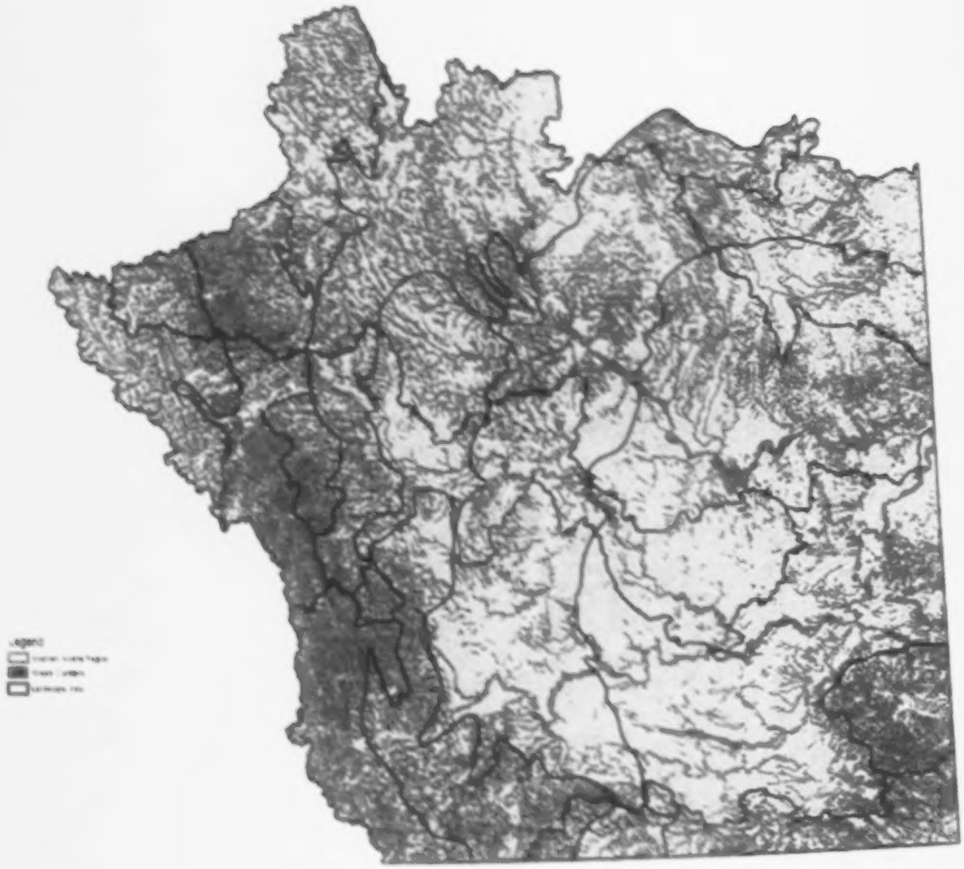


4.2 Natural Vegetation Patches and Stepping Stones

Guidelines for natural patch size are often dependent on a target species, although some studies describe the patch size required to sustain ecological functions (e.g., primary productivity, nutrient and hydrological cycling, disturbance regimes). Species-dependent guidelines for patch sizes can range from 4 m^2 (for some invertebrates) up to 220 000 ha for wide-ranging mammals such as bears and cougars (Kennedy et al. 2003). The requirements of other species, such as grassland butterflies, may be more modest. A two-hectare minimum patch size was suggested for butterfly species in Oregon (Schultz and Crone 2005). Small mammals (e.g., rodents) make use of patches of 1 to 10 ha in size (Kennedy et al. 2003). In Illinois, Herkert et al. (1993) showed that patches of 20 ha benefited the least area-sensitive avian species, and patches of 50 to 100 ha benefited the species with greater fragmentation sensitivity. Some wetland birds (e.g., willets, marbled godwits) require grassland patches larger than 100 ha for nesting and brood-rearing cover (Fitzgerald et al. 1999). In areas with hard boundaries and no semi-natural adjacent habitat such as pasture, minimum patch area to support grassland species increases. Two hundred hectares is recommended for grassland patch size in these situations (USDA 1999). The *Partners In Flight* bird conservation areas model recommends that a block of high-quality grassland (minimum 800 ha in size) be maintained as a core area within a 1.6 km wide 'buffer' that provides another 1000 ha of additional grassland habitat (Fitzgerald et al. 1999). Flocks of other grassland species such as greater prairie chickens and sharp-tailed grouse require grassland patches up to 4000 ha in size, similar to meso-carnivores such as the swift fox (Fitzgerald et al. 1999). When interconnected, a system of patches of over 100 ha in size starts to encompass a variety of habitats that can support populations of medium-sized animals such as coyotes and hawks (Barnes and Adams 1999). Patches of over 5000 to 10 000 ha in size start to protect ecosystem integrity and function, providing a wide variety of habitat types for a full range of small-, medium- and large-sized animals (Barnes and Adams 1999, Kennedy et al. 2003, Amos 2004).

Landscape connectivity is perceived differently by different organisms (Andersson 2006). Inter-patch distance (the distance species will travel over unsuitable habitat to reach another patch) depends on the species in question. Deer mice in prairie and badlands were found to travel approximately 60 m to forage and have a 140 m effective dispersal distance (Morris 1992). Other animals have slightly larger dispersal ranges. Frogs, salamanders and small mammals often do not travel more than 300 m from a suitable habitat patch, and reptiles travel only slightly further to a 500 m distance from a patch (Gibbs 2000). Flying animals tend to have greater thresholds for inter-patch distances, although small birds will often not travel more than 200 m to neighbouring habitat (Kampf and Stavast (2005). Schultz and Crone (2005) recommend that suitable habitat patches remain within 1 km of each other for prairie butterfly species, and Herkert et al. (1993) recommend that habitat patches for grassland birds are within 1.6 km of each other.

Stepping stones are discrete patches of natural habitat functionally connected within a given distance. As distance between stepping stones increases, so does the composition of plant pollinators (Steffan-Dewenter and Tscharntke 1999).

Having a diversity of native pollinators is important because of the strong temporal fluctuations that occur naturally in pollinator populations (Kremen *et al.*, 2002). This ecosystem service is particularly important in agricultural areas.

However, even isolated patches have value, especially if they represent high-quality habitat. Isolated wetlands, for example, have demonstrated ecological value in terms of maintaining metapopulation connectivity for semi-aquatic species (Gibbons et al. 2006).

In Southern Alberta, natural patches of vegetation were classified into several functional categories based on area (Table 4.1).

Table 4.1. Size classes for natural patch size distribution analysis.

Patch Size	Function	Reference
< 2 ha	invertebrate habitat act as 'outliers' of natural habitat	Forman 1995 Kennedy et al. 2003
2 - 50 ha	act as stepping stones and provide habitat for small mammals and small grassland birds (e.g., grasshopper sparrow, dickcissel)	Herkert et al. 1993 Helzer and Jelinski 1999 USDA 1999 Walk and Warner 1999 Smallwood 2001 Smith Fargey 2001 Kennedy et al. 2003
50 - 100 ha	act as stepping stones and provide habitat for small- to medium-sized birds and mammals (e.g., upland sandpiper, savannah sparrow)	Herkert et al. 1993 Helzer and Jelinski 1999 Walk and Warner 1999 Johnson and Igl 2001
100 - 1000 ha	benefit populations of medium-sized animals (e.g., coyote, hawk) when the patches are interconnected offer habitat for wetland birds (e.g., willet, marbled godwit) and small mammals conserve core grassland bird habitat, especially when surrounded by low-intensity land uses	Herkert et al. 1993 Barnes and Adams 1999 Fitzgerald et al. 1999

Patch Size	Function	Reference
1000 - 10 000 ha	start to protect ecosystem integrity and function accommodate species with large home ranges (e.g., swift fox, sharp-tailed grouse) provide a wide variety of habitat types for a full range of small-, medium- and large-sized mammals	Barnes and Adams 1999 Fitzgerald et al. 1999 Downey et al. 2004
> 10 000 ha	sustain viable ecological processes in the long term may accommodate species with the largest home ranges (e.g., bear, cougar)	Amos 2004

In addition, the five largest patches of natural vegetation in each LMU were identified. Four or five large patches are required in a landscape where any single patch contains a limited proportion of the species pool (Forman 1995, Dramstad et al. 1996).

Stepping stones also have significant ecological value, including:

- enhancing / ensuring connectivity for a full range of species across the landscape;
- recharging depleted gene pools for various species;
- providing habitat for some smaller species (e.g., small mammals, grassland birds, wetland species nesting in grasslands); and,
- in the absence of a large patch, some generalist species can survive in a number of well-connected smaller patches (Dramstad et al. 1996).

For the purposes of this project and at the regional, stepping stones were functionally defined by movement patterns demonstrated by medium-sized mammals and birds. Thus, stepping stones were defined as natural patches between 50 and 100 ha in size which provide connectivity value when clustered within a functional distance of 500 m (Kampf and Stavast 2005). At a smaller scale, stepping stones for small birds and mammals may be appropriate (e.g., natural patches between 2 to 50 ha connected within 200 m of each other).

4.2.1 Data and Assumptions

All natural vegetation was selected from the integrated southern Alberta inventories and dissolved into a region-wide dataset of natural vegetation. Patch sizes were calculated and the patch size distribution mapped.

Due to the large size of the data, processing had to be done in ArcInfo Workstation and then translated back into ArcGIS 9.2. Since data attributes are lost in translation, the type of natural landcover (e.g., grassland, shrub, forest) cannot be determined after the dissolve. A 'natural patch' can therefore be

comprised of many different types of native vegetation. Without this processing constraint or if this analysis was performed on fewer polygons at a finer scale, an additional step could be taken for identifying patches of native grassland. For grassland polygons, all native grassland types within each polygon could be summed and the total compared to a 70% threshold value to determine whether the polygon could be considered 'natural vegetation' (Bunce et al. 2005). This summed area of native grassland could then be used to determine the area of a large grassland patch rather that the total polygon area in order to avoid over-reporting of natural patch sizes. The accuracy of the natural patch analysis output is the same as the accuracy of the integrated southern Alberta inventories data.

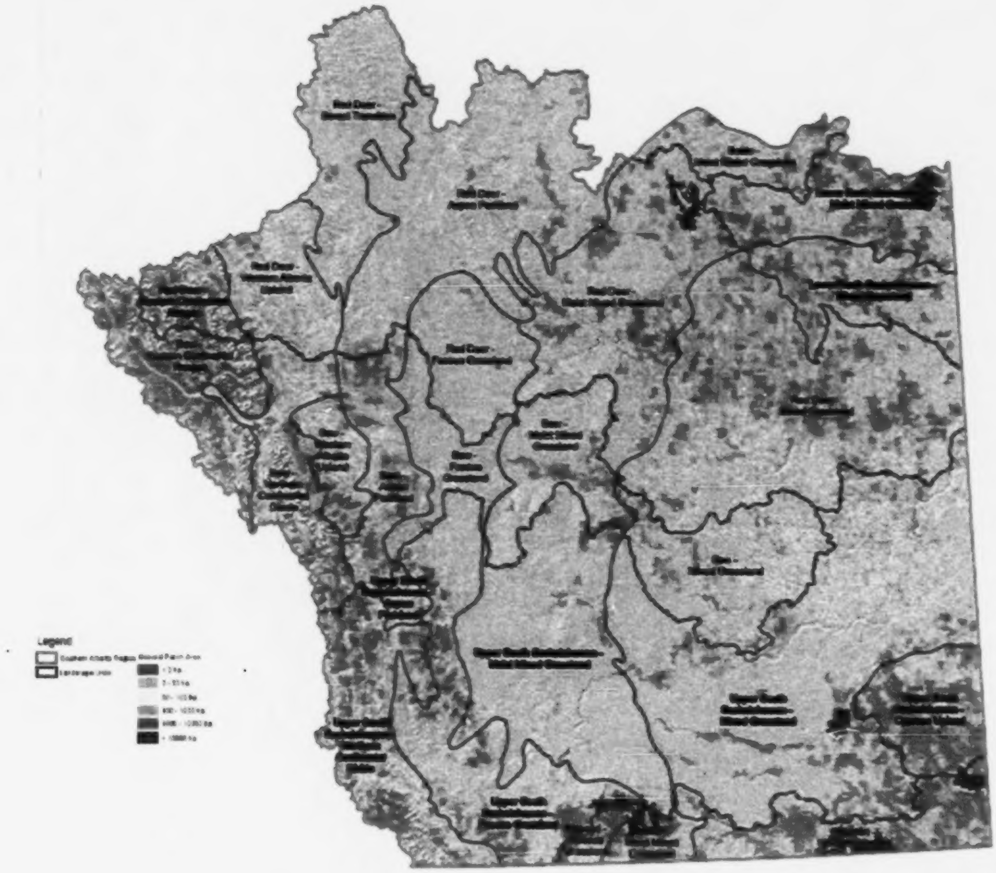
4.2.2 Model

A flow diagram of the ArcGIS 9.2 model is presented in Appendix C. The model is located in an ArcGIS Toolbox in the following location:

C:\EIM\Tools\Toolboxes

The results of the model over the entire Southern Alberta region are presented in Figure 4.3.

Figure 4.3. Natural patch sizes in Southern Alberta.



4.3 Waterbody Complexes

Waterbody complexes are areas of permanent or intermittent wetlands and bodies of water connected by narrow patches of natural vegetation.

Wetlands include areas that are temporarily, seasonally or permanently covered by shallow water and contain wet vegetation. Wetlands represent hotspots of biodiversity, and the prairie pothole wetlands have been described as the most important waterfowl breeding ground in North America as well as an important staging area for migrating shorebirds (Canadian Prairie PIF 2004).

Ecological values of wetlands and waterbody complexes include:

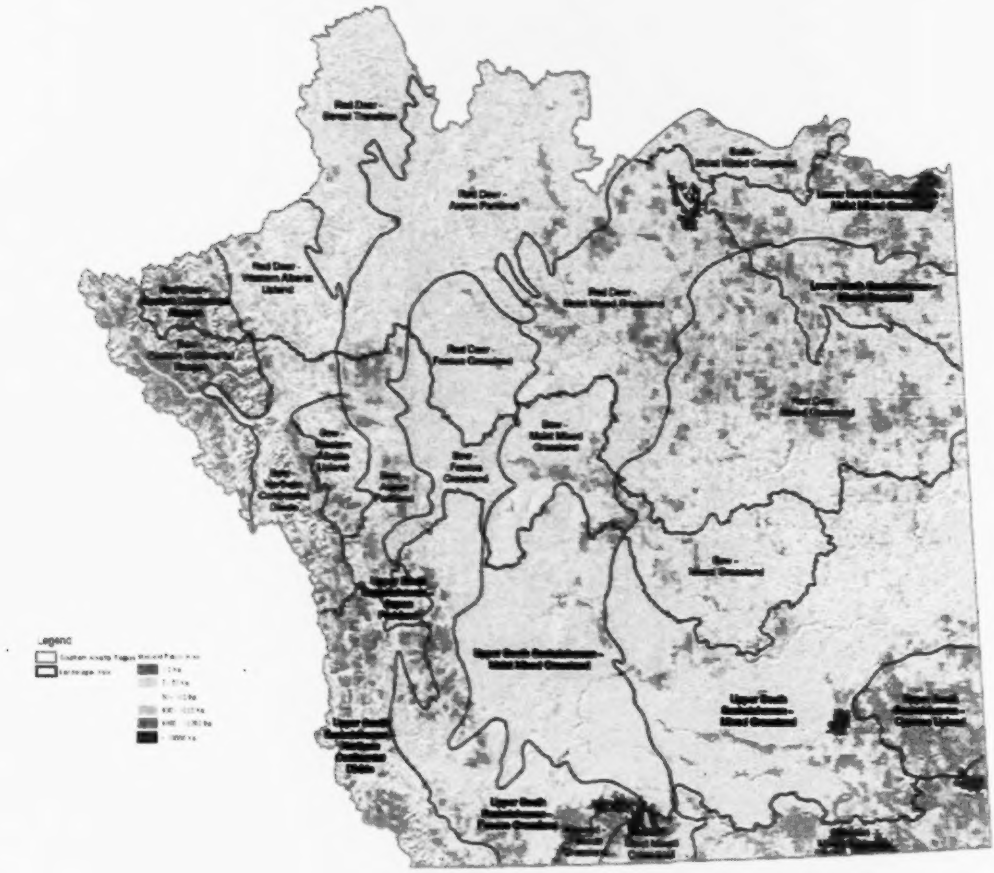
- important groundwater / surface water connection and groundwater recharge;
- productive wildlife habitat for resident and migratory species;
- buffer protects breeding and nesting habitat for waterbirds (EC 2004, Horn et al. 2005);
- wetland complexes have very high biodiversity and can provide benefits similar to those of large patches (Huel 2000);
- vegetated buffers prevent movement of salts and sediment into cropland and slow soil erosion (SWCC 1996, Huel 2000); and,
- water storage, recharge and flood control functions (SWCC 1996, Huel 2000).

Wetlands, including prairie potholes and riparian wetlands, should be surrounded by natural cover to protect their function and habitat value. In terms of water quality protection, Madison et al. (1992) found that grass filter strips >5 m wide removed 90% of nitrates and phosphorus. Huel (2000) recommended a 10 m minimum buffer to maintain wetland water quality in Saskatchewan.

Environment Canada's (EC 2004) review found that a huge range of 6-104 m was found to protect wetlands from agricultural herbicide drift, nitrates, and non-point source agricultural pollution. Grass buffer widths of 10-60 m around isolated wetlands appeared to be adequate for trapping most sediments in runoff (Melcher and Skagen 2005).

In terms of wildlife habitat, nesting waterfowl use a varying width of natural vegetation around wetlands with 90% of waterfowl nesting within 200 m of the wetland (EC 2004). Most nests in the Prairie Pothole Region are within 300 m of wetland edges (Horn et al. 2005). Small predators such as striped skunk and red fox tend to hunt within 50 m of wetlands (Horn et al. 2005), so buffer widths larger than 50 m would tend to reduce predation on nesting species. A buffer zone of approximately 165 m around a wetland would capture 95% of *Ambystoma* salamander populations (Horn et al. 2005). Huel (2000) recommended maintaining a 3:1 ratio of upland permanent cover to wetland area around each wetland to maintain wildlife use of wetlands in Saskatchewan. This buffer size was corroborated by Sargent and Carter (1999), who recommends an area of permanent grassland three to six times larger than the wetland itself to maximize benefits to nesting species.

Figure 4.3. Natural patch sizes in Southern Alberta.



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A suggestion for wetland buffers that integrates the need for water quality protection and wildlife habitat is to keep a 10 m buffer of permanent vegetation around each wetland and then maintain a second buffer of 100 m in semi-natural land such as forage or pasture managed with wildlife-friendly methods (e.g., deferred grazing, late hay cut, etc.; e.g., Huel 2000, EC 2004, Gabor et al. 2004).

Wetlands surrounded by a 100 m buffer of perennial vegetation are valuable in terms of both water quality protection and wildlife use (EC 2004, Horn et al. 2005, Semlitsch 1998). A 100 m buffer was therefore chosen for the scale of the current project.

4.3.1 Data and Assumptions

In the grassland areas, there are some intermittent waterbodies present in the AltaLIS data that were not in the integrated southern Alberta inventories land cover. Therefore, intermittent waterbodies and wetlands from AltaLIS hydrography polygon data were added to the integrated southern Alberta inventories permanent waterbody and wetland data to form a complete waterbodies data set. In forested areas, waterbodies and wetlands in the integrated southern Alberta inventories were used.

All waterbodies and wetlands were buffered by 100 m and clumped to identify overlapping areas. Waterbody complexes were defined as areas consisting of two or more waterbodies or wetlands connected within 200 m where the total wetland / water body area is greater than 5 ha (BCMOFR 1995).

Due to the size of the integrated southern Alberta inventories, it was necessary to pass some of the model processing to ArcInfo workstation to avoid having errors due to memory limitations in ArcGIS 9.2. The accuracy of the waterbody complex output dataset is the same as the accuracy of the integrated southern Alberta inventories data.

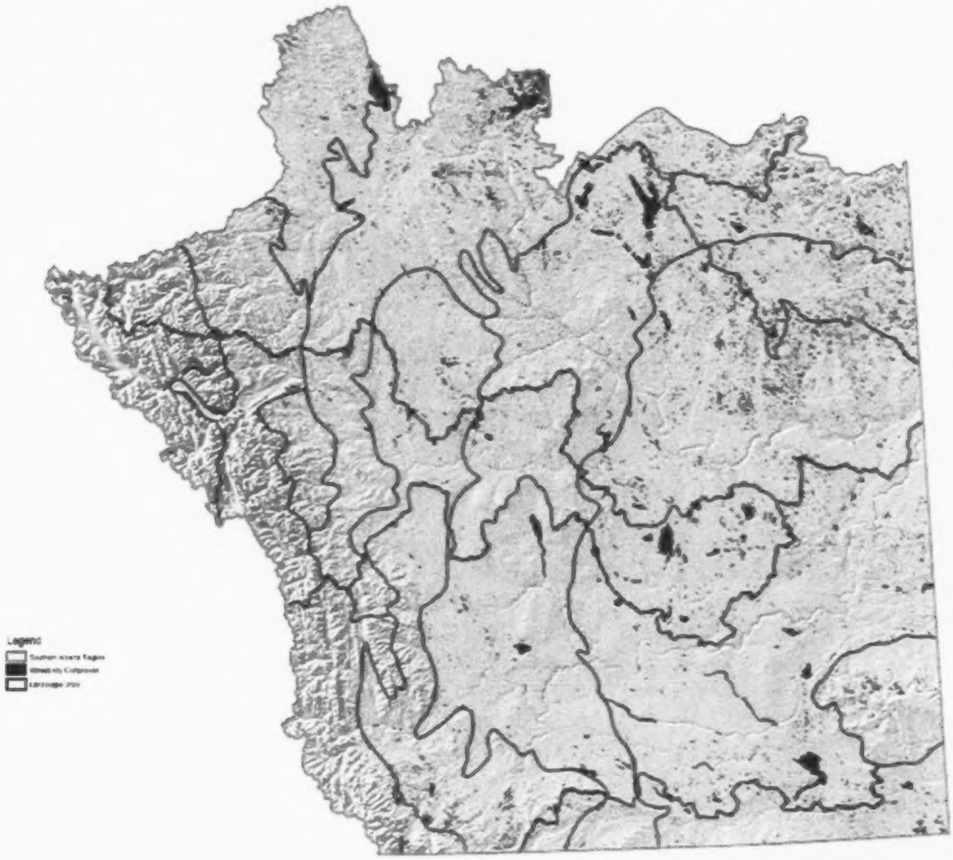
4.3.2 Model

A flow diagram of the ArcGIS 9.2 model is presented in Appendix C. The model is located in an ArcGIS Toolbox in the following location:

C:\EIM\Tools\Toolboxes

The results of the model over the entire Southern Alberta region are presented in Figure 4.4.

Figure 4.4. Waterbody complexes in Southern Alberta.



4.4 Areas of High Species Richness Potential

Species richness is a measurable characteristic of environmental condition and is often used as a surrogate for biodiversity, among other methods. Species richness is a relatively simple way to evaluate biodiversity and refers to the number of species overall, or within specific taxa, which exist within a defined area. Species richness is often measured at very large scales: states (Scott et al. 1993), ecoregions (Davis et al. 1999), countries (Prendergast et al. 1993) or continents (Ricketts et al. 1999).

Areas of high species richness potential for terrestrial vertebrates were identified in order to protect habitats of high wildlife value in Southern Alberta. Species richness mapping uses species-habitat associations to map the number of species potentially present in a land polygon. If a species uses a given habitat type it receives a '1'; if the species does not use that habitat it receives a '0'. This binary habitat association matrix is then used to associate a number of species to each habitat type on the map, clipped to individual species ranges.

An analysis of surrogate measures of biodiversity found that species richness was an immediate and ready source of information on biodiversity at large scales because of the ease of obtaining broad-scale geographic distribution information but is not the best biodiversity surrogate at finer scales as rare species are typically under-represented (O2 Planning + Design Inc. et al. 2007). Thus, species richness maps require careful interpretation if used for biodiversity planning as the areas of high species richness may not represent the full range of species present in the area. Rare species occupy a small amount of the total biomass of a region and may play a disproportionate role in the ecosystem. Greater attention to areas containing instances of rare or endemic species may be desired during planning processes.

If more detailed biodiversity planning is required, rarity-weighted species richness mapping may be considered. For this process, the habitat association matrix is inversely weighted by the area each species occupies. Thus, species found throughout the region of interest are given zero weight while species found in only one area are weighted as 1. By summing each weighted species incidence, a rarity-weighted richness map may be produced where high values indicate the presence of endemic and specialist species and low values indicate more common species assemblages.

For the current assessment, mapping of straight species richness potential was thought sufficient for ecological infrastructure mapping of Southern Alberta, in combination with the other components.

4.4.1 Data and Assumptions

The habitat association matrices from NAESI and AAFC range data (see Appendix A) were used to identify species occurring within the Southern Alberta region (Appendix D). A complete usage matrix was coded for all cover types so that a value of '1' denoted species use of that cover type and a value of '0' denoted that the species did not use that cover type. In grassland areas, cover type was determined by assigning the dominant cover type to the polygon if the

polygon was considered 'natural' (>70% native vegetation cover; see Section 4.2.1). Values were summed across the region to show the total number of species using each polygon. Species were spatially limited by their ranges or by the natural subregions in which they occurred. The accuracy of the species richness output dataset is the same as the accuracy of the CanSIS soil polygon data (1:1 000 000).

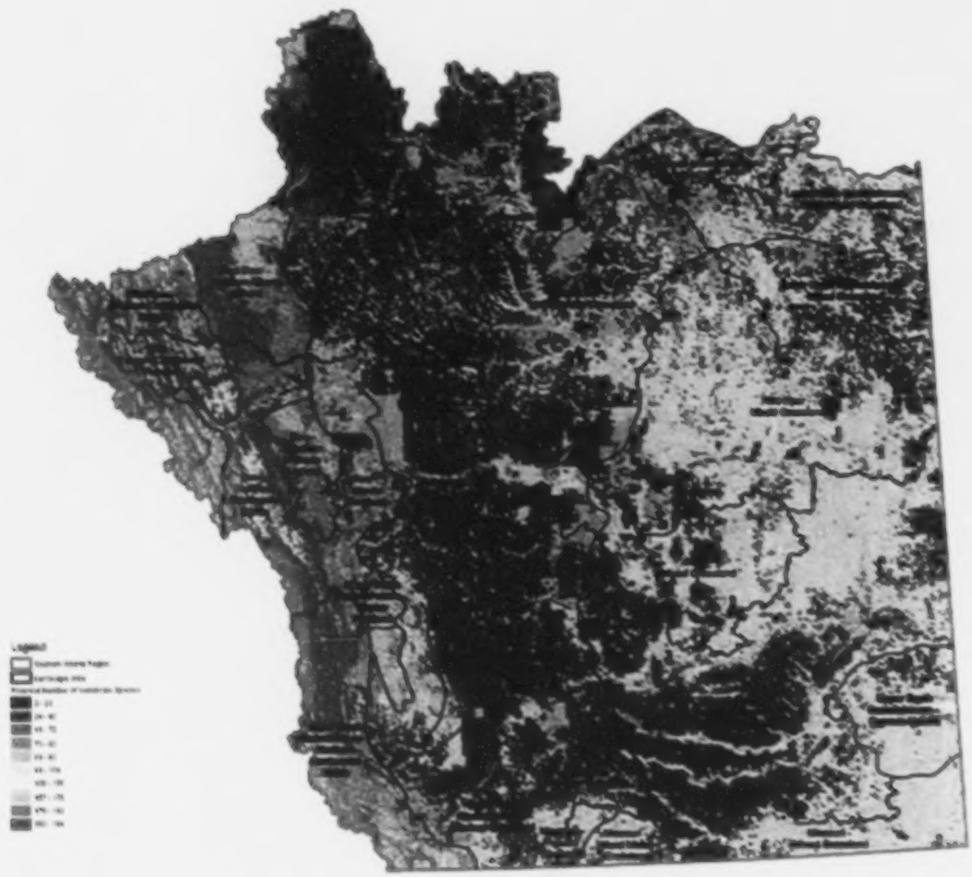
4.4.2 Model

A flow diagram of the ArcGIS 9.2 model is presented in Appendix C. The model is located in an ArcGIS Toolbox in the following location:

C:\EIM\Tools\Toolboxes

The results of the model over the entire Southern Alberta region are presented in Figure 4.5.

Figure 4.5. Species richness potential in Southern Alberta.



4.5 Alluvial Soils

Alluvial soils are formed by streams that deposit suspended material in response to a decrease in velocity. The resulting sediments are well-sorted and coarse textured, which generally means high porosity (Dunne and Leopold 1978) and the ability to store water and allow for subsurface flow. Fine particles of silt and clay are typically deposited above larger particles of sand and gravel.

Alluvial soils often represent areas of important groundwater / surface water connections, contributing to both shallow and deep groundwater recharge. These sites may be ideal for cottonwood forests which provide unique habitat to a wide range of plant and animal species (Willms et al. 2006). Alluvial soils also support higher productivity through greater moisture availability (Bennett 1999) and may be a contributing factor to increased biodiversity in those areas.

Alluvial soils represent sensitive ecological areas for a variety of reasons. Removal of groundwater in shallow alluvial soils adjacent to streams may be equivalent to direct removal from the stream itself due to the high connectivity between the stream and the surrounding saturated soils. In cases where alluvial soils are directly adjacent to streams and rivers, they may directly influence both stream flow and water quality. Being permeable, alluvial and other coarse textured soils are sensitive areas that may lead to the contamination of groundwater aquifers through inappropriate land use. For example, wastewater treatment methods in areas of alluvial soils under direct stream influence can seriously impact water quality. Therefore, septic fields should be restricted in these areas, with particular emphasis on those areas adjacent to streams that are potable water sources. Point and non-point pollution from agriculture and industrial uses in these areas can also be especially problematic.

4.5.1 Data and Assumptions

Alluvial soils were identified in grassland landscapes from AGRASID data; however, AGRASID does not cover forest soils. Since the scale of CanSIS soils data in the forest areas is too broad, it was decided that an analysis of alluvial soils in forest landscapes would not be run in the scope of this project but may be used in later phases if finer-scale data becomes available.

AGRASID soils having a primary parent materials with fluvial or undifferentiated textures were selected from the AGRASID data and then spatially compared to the 100 m stream buffers for all named streams from the AltaLIS 1:20000 base hydrography. The accuracy of the alluvial soils output dataset is the same as the accuracy of the AGRASID soil polygon data (1:100 000).

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C:\EIM\Tools\Toolboxes

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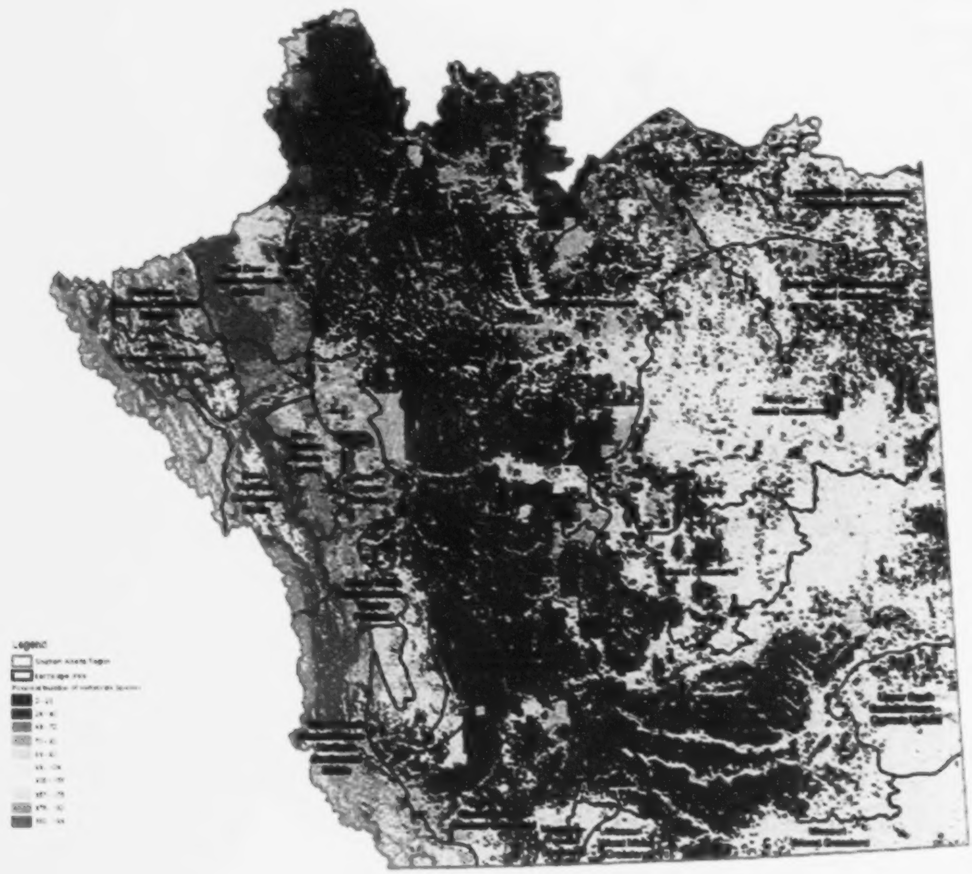

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4.5.2 Model

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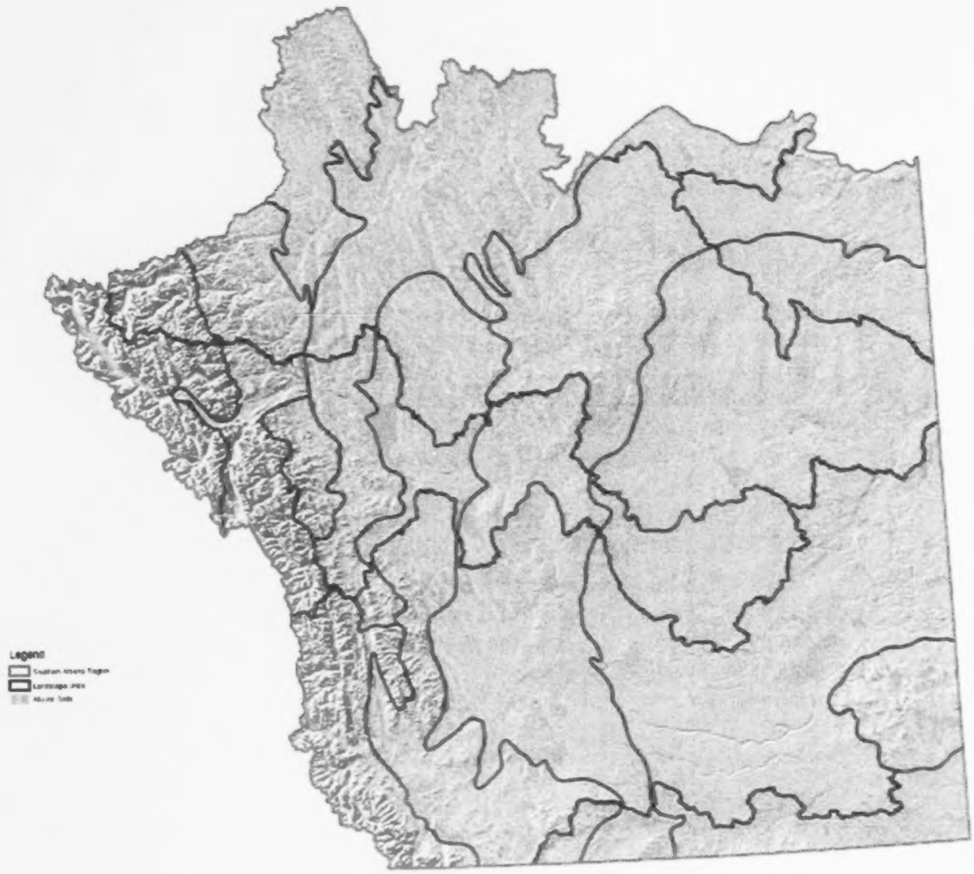
C:\EIM\Tools\Toolboxes

The results of the model over the entire Southern Alberta region are presented in Figure 4.6.

Figure 4.6. Alluvial soils in Southern Alberta.



4.6 Unique Land Cover Types or Areas

Unique, special or valued land cover types or areas represent specific environmental components of ecological significance. Features identified under this heading include ridge topography and low percentage cover types. Wetlands are also often considered as unique or special land cover types; however, these have been called out as a separate heading due to their ecological importance in Southern Alberta. Mapping these areas can help capture those species and ecological processes missed by species richness potential mapping, which often under-represents rare species.

4.6.1 Ridge Features

Many physical and biological processes are highly correlated with topographic position on the landscape (Weiss nd.). Ridges, like stream corridors, are continuous linear landscape features that provide natural corridors for landscape connectivity. Ridges provide important movement corridors for wildlife (Quinn, pers. comm., 2007). Wildlife corridors that contain a variety of topographic positions typically support more species and a greater abundance of animals than a single topographic position such as a midslope (Lindenmayer and Nix 1992).

4.6.1.1 Data and Assumptions

A broad-scale landform analysis was performed using a topographic position index (TPI) function (Weiss nd.) performed at two separate scales – one larger and one smaller – and a classification authored by Andrew Jenness. The TPI compares the elevation of each cell in a DEM to the mean elevation of a specified neighbourhood around that cell (Weiss nd.). Positive TPI values represent locations higher than the surrounding average (e.g., ridges) while negative TPI values represent lower than average values (e.g., valleys).

In this case, the parameters used for the larger TPI were an outer radius of 1000 m and an inner radius of 975 m. The parameters used for the smaller TPI were an outer radius of 100 m and an inner radius of 75 m. The two TPI rasters were standardized in preparation for classification using the formula:

$$\text{Standardized TPI} = \{[(\text{TPI} - \text{Mean TPI}) / \text{TPI Standard Deviation}] * 100\}$$

The resulting classification categories include:

1. canyons, deeply incised streams
2. midslope drainages, shallow valleys
3. upland drainages, headwaters
4. U-shape valleys
5. plains
6. open slopes
7. upper slopes, mesas
8. local ridges / hills in valleys

9. midslope ridges, small hills in plains
10. mountain tops, high ridges

These categories are extremely scale-dependent, however. Soil transport, water balance, and species movement and distribution may be affected at the scale used in this analysis (Weiss nd., Guisan et al. 1999).

This analysis identified very few ridges of moderate size that were not mountain tops. The landform analysis can be performed at varying scales to isolate landforms of varying sizes. It is recommended that a smaller extent be used if the radii of the larger TPI are increased to avoid the very long processing times that can result. It is also recommended that the topography of the areas be relatively similar throughout the analysis area. Better results can be obtained by performing this analysis on a mountainous region separately from a flat region to avoid skewing the distribution of elevations into data that is no longer normally distributed. The accuracy of the output landform classification is equal to the DEM accuracy.

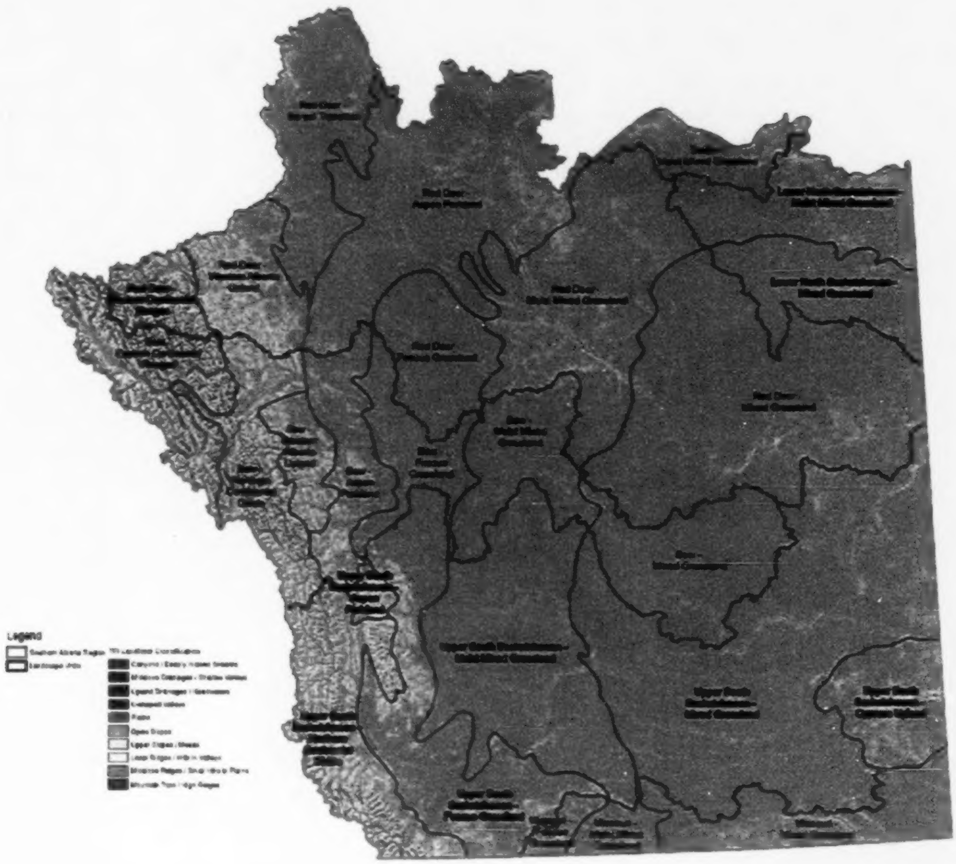
4.6.1.2 Model

A flow diagram of the ArcGIS 9.2 model is presented in Appendix C. The model is located in an ArcGIS Toolbox in the following location:

C:\EIM\Tools\Toolboxes

The results of the model over the entire Southern Alberta region are presented in Figure 4.7.

Figure 4.7. Landform classification for Southern Alberta.



4.6.2 Low Percentage Cover Types

These are areas of unique ecology that may provide special ecosystem services and contribute to regional biodiversity value. For example, badlands typically cover very little of the landscape in terms of area but are important for specialized, rare and often sensitive species (e.g., short-horned lizard) that contribute to regional biodiversity and ecological processes (Powell 2005).

Low percentage cover types were defined as those that cover less than 6% of the landscape or regional area (O2 Planning + Design Inc. et al. 2007). In Southern Alberta, these cover types include:

Forest Portion of Southern Alberta

- Douglas fir
- forest riparian
- forest shrub
- lentic
- lentic large
- lentic small
- lotic
- lotic large
- lotic small
- mixedwood

Agricultural Portion of Southern Alberta

- pine
- white spruce & forest riparian
- hardwood
- grassland shrub
- prairie treed & riparian complexes
- needle & thread sand grass DMG
- mixed grass
- fescue grassland
- fescue parkland
- badlands
- water

4.6.2.1 Data and Assumptions

The integrated southern Alberta inventories land cover was used to identify the proportion of each land cover type across both the forested and agricultural portions of Southern Alberta.

Low percentage cover types analysis was performed separately on the forest and grassland portions due to the difference in land cover types. Total areas for each cover type throughout each portion were calculated and cover types occupying less than 6% of the respective portion were identified. The accuracy of the low percentage cover type analysis output is the same as the accuracy of the integrated southern Alberta inventories dataset.

4.6.2.2 Model

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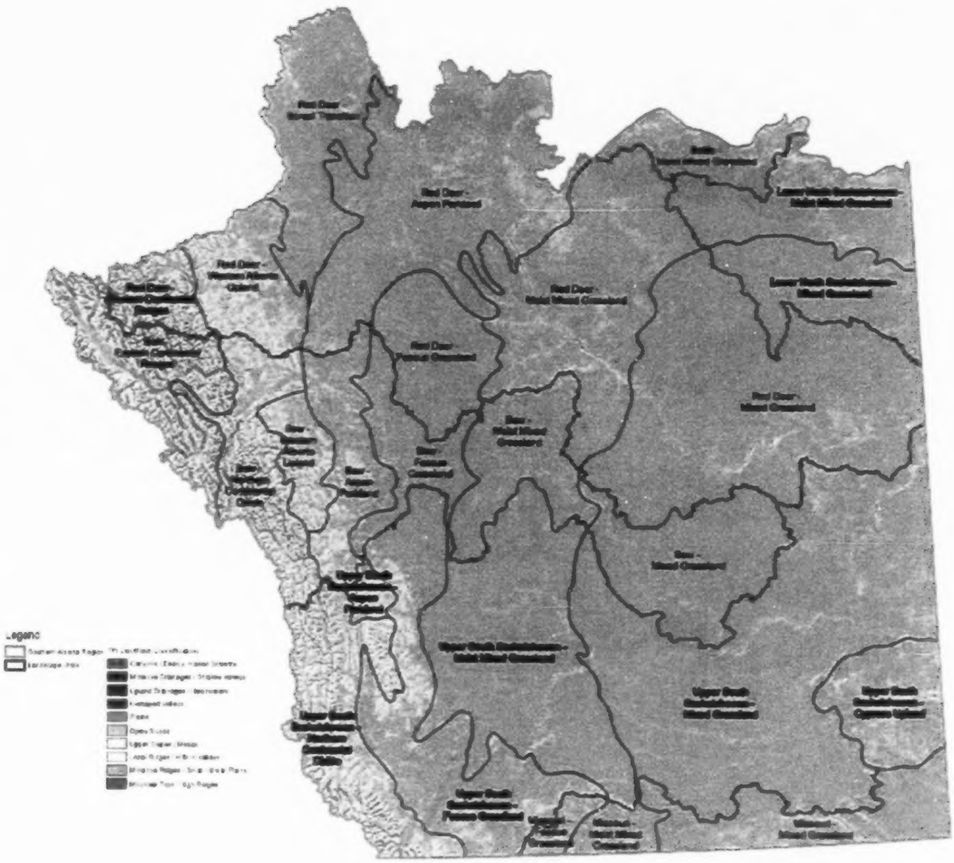

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- fescue parkland
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- water

4.6.2.1 Data and Assumptions

The integrated southern Alberta inventories land cover was used to identify the proportion of each land cover type across both the forested and agricultural portions of Southern Alberta.

Low percentage cover types analysis was performed separately on the forest and grassland portions due to the difference in land cover types. Total areas for each cover type throughout each portion were calculated and cover types occupying less than 6% of the respective portion were identified. The accuracy of the low percentage cover type analysis output is the same as the accuracy of the integrated southern Alberta inventories dataset.

4.6.2.2 Model

A flow diagram of the ArcGIS 9.2 model is presented in Appendix C. The model is located in an ArcGIS Toolbox in the following location:

C:\EIM\Tools\Toolboxes

The results of the model over the entire Southern Alberta region are presented in Figure 4.8.

Figure 4.8. Low percentage land cover types in Southern Alberta.

The results of the model over the entire Southern Alberta region are presented in Figure 4.8.

Figure 4.8. Low percentage land cover types in Southern Alberta.

5.0 Conclusions and Implications

The stream corridors map shows a high density of stream corridors in the forested landscapes to the west and southeast; very few corridors exist in the central Southern Alberta region (e.g., in the LUs Bow-Fescue Grassland, Bow-Mixed Grassland, Upper South Saskatchewan-Mixed Grassland, Upper South Saskatchewan-Moist Mixed Grassland) (Figure 4.2). In this area, stream corridors will be especially critical to maintaining ecosystem goods and services.

The natural patch size analysis revealed the location of large natural patches in Southern Alberta (Figure 4.3). The largest patches of natural vegetation over 10 000 ha in size were located in the southeast (Missouri-Moist Mixed Grassland, Missouri-Fescue Grassland and Missouri-Mixed Grassland) and northeast (Red Deer-Moist Mixed Grassland, Lower North Saskatchewan-Moist Mixed Grassland). Although there were many large patches in the western forested LUs, there were no natural patches >10 000 ha. The central part of Southern Alberta had few large patches of natural vegetation, and those that remain in this area will be regionally valuable.

The greatest concentration of waterbody complexes is in the northeast portion of Southern Alberta, which has a number of small complexes of standing water (Red Deer-Mixed Grassland, Red Deer-Moist Mixed Grassland, Lower North Saskatchewan-Mixed Grassland, Lower North Saskatchewan-Moist Mixed Grassland, Battle-Moist Mixed Grassland) (Figure 4.4). These areas all are important as areas of localized moisture in a predominantly dry region. Wetlands and water bodies in large complexes are important for biodiversity and ecosystem processes, as species can easily migrate to the next closest wetland if one dries up. Slightly larger waterbody complexes are found in the Red Deer-Aspen Parkland LU in the north and the Bow-Mixed Grassland in the centre of the region. Large, permanent wetlands and waterbodies are important for many neotropical migrants and overwintering amphibians, as well as many other ecosystem services such as climate and water regulation and cultural and aesthetic services. The western portion of Southern Alberta has few areas of standing waterbodies, but the complexes that exist along stream corridors are also of value.

Species richness mapping across Southern Alberta shows the highest species richness potential in the forested hills running north-south between the mountain peaks and the shrubby parkland habitats at the base of the foothills (Figure 4.5). There is also high species richness potential in the southeast around the Cypress Hills area. While native grassland also has high potential for species richness, the overall number of species with ranges covering the western forested portion of the region is greater than in the agricultural portion. In addition, forests have a vertical which adds to habitat diversity and thus high species richness potential. When the top five classes (highest 50%) of species rich areas are selected, however, both grasslands and forests as well as riparian and wetland cover types are picked out. Within the forested portion of Southern Alberta, cutblocks appear as low species richness potential. While these are considered 'grassland' in the integrated southern Alberta inventories landcover data, these blocks are outside the ranges of grassland species and thus contain few species. This is likely a good check on the legitimacy of the method.

Locations of alluvial soils are spread out around the outsides of the region with a couple thin bands reaching across the central grasslands (Figure 4.6). The base of the Rocky Mountains along the western border of Southern Alberta show a high concentration of alluvial soils; this is logical, as most streams traveling quickly through the hills would slow down upon reaching flatter terrain and deposit their suspended sediments along the edges of the foothills. A similar spatial pattern is shown in the Cypress Hills area to the southeast. These areas are extremely important in terms of water quality and quantity protection.

The landform classification (Figure 4.7) was not found to be very accurate at this large scale, as it averaged the results into a few middle landform categories. The map still shows general features of the mountains to the west and coulees across the agricultural areas, but it would be a more effective model at a finer scale.

Low percentage cover types differ considerably between the forested and the agricultural portion of Southern Alberta (Figure 4.8). In the agricultural portion (the central and eastern portion), patches of native grassland can be seen interspersed throughout with a large area of mixed grass around the Cypress Hills. Patches of fescue grassland are located near the base of the foothills. Other low percentage cover types in the agricultural portion include native trees and shrubs such as pine and white spruce / forest riparian; these represent only small portions on the map. In the forested portion, the patches of low percentage cover types are smaller and patchier than in the agricultural portion. Mixedwood is one low percentage cover type that is particularly high in biodiversity and other ecosystem goods and services (Integrated Environments (2006) Ltd. and O2 Planning + Design Inc. 2007b).

6.0 Effects on Ecosystem Goods and Services

There is a direct, though not necessarily linear, relationship between the condition of natural assets and the type, quantity and quality of ecosystem services they provide. From a macro-scale perspective, the condition of natural assets varies depending on the spatial configuration and connectivity of natural assets in the region and the composition of the surrounding landscape. For example, a hectare of native grassland within a large patch of 1000 ha of grassland will provide greater ecosystem services such as biodiversity and climate regulation than an isolated hectare of grassland within an urbanized area. While both are important to landscape and environmental goals, the former hectare of grassland is in better condition with respect to ecosystem goods and services provision. Section 4.4 in the *Ecosystem Goods and Services Assessment – Southern Alberta Phase 2 Report* describes the relationship between asset condition and EGS (Integrated Environments (2006) Ltd. and O2 Planning + Design Inc. 2007).

The effect of landscape configuration and connectivity (defined through ecological infrastructure) on ecosystem services is demonstrated in Table 6.1.

A coincidence of analysis between the components of ecological infrastructure and each group of ecosystems services (regulating, supportive, provisioning and cultural; see Table 6.1) was conducted. The analysis involved first rasterizing each of the components of ecological infrastructure based on the majority value within each 1 ha pixel. This pixel resolution was considered appropriate to the resolution of the data. To create a combined map of all ecological infrastructure components, two methods were used. In the first, a binary map was created in which each pixel containing at least one of the ecological infrastructure components was given a value of '1' while all other pixels were assigned a '0'. In the second map, an additive map was created in which each pixel was assigned a sum value of each ecological infrastructure component it included. Thus, a pixel that represented a stream corridor within a large patch of natural vegetation in an area of high species richness potential was assigned a '3', while a pixel that represented a stream corridor on its own was assigned a '1'. Pixels not covered by any ecological infrastructure components were given a value of '0'. This map gives a range of values between '0' and '6', '6' being the maximum possible value a pixel could be assigned (i.e., an area that represented a stream corridor, a waterbody complex, an area of high species richness potential, alluvial soils, a low percentage cover type, and either part of large patch or a stepping stone complex) (Figure 6.1). This map shows the relative contribution of each map pixel to regional ecological infrastructure. The high value of several landscape units to overall regional ecological infrastructure is evident (e.g., Upper South Saskatchewan-Cypress Upland, Missouri-Moist Mixed Grassland, Missouri-Fescue Grassland, Upper South Saskatchewan-Fescue Grassland, among others)

Table 6.1. Ecosystem services on which the components of ecological infrastructure have the greatest impacts.

Ecological Infrastructure Components	Regulating Services							Supporting Services					Provisioning Services				Cultural and Aesthetic Services			
	Gas regulation	Climate regulation	Disturbance regulation	Water regulation	Erosion control and sediment retention	Waste treatment	Biological control	Soil formation	Primary productivity	Nutrient cycling	Pollination	Habitat / refugia	Water supply	Food production	Raw materials	Genetic resources	Aesthetic	Spiritual and traditional use	Science and education	Recreation
Stream corridors	x	x	x	x	x	x				x	x	x	x	x			x	x	x	x
Natural vegetation patches and stepping stones	x	x	x				x		x		x	x	x	x	x	x	x	x	x	x
Waterbody complexes	x	x	x	x	x	x			x	x		x	x	x			x	x	x	x
Areas of high species richness potential							x				x	x				x			x	x
Alluvial soils			x	x		x							x						x	
Unique land cover types or areas					x		x	x				x			x	x	x	x	x	

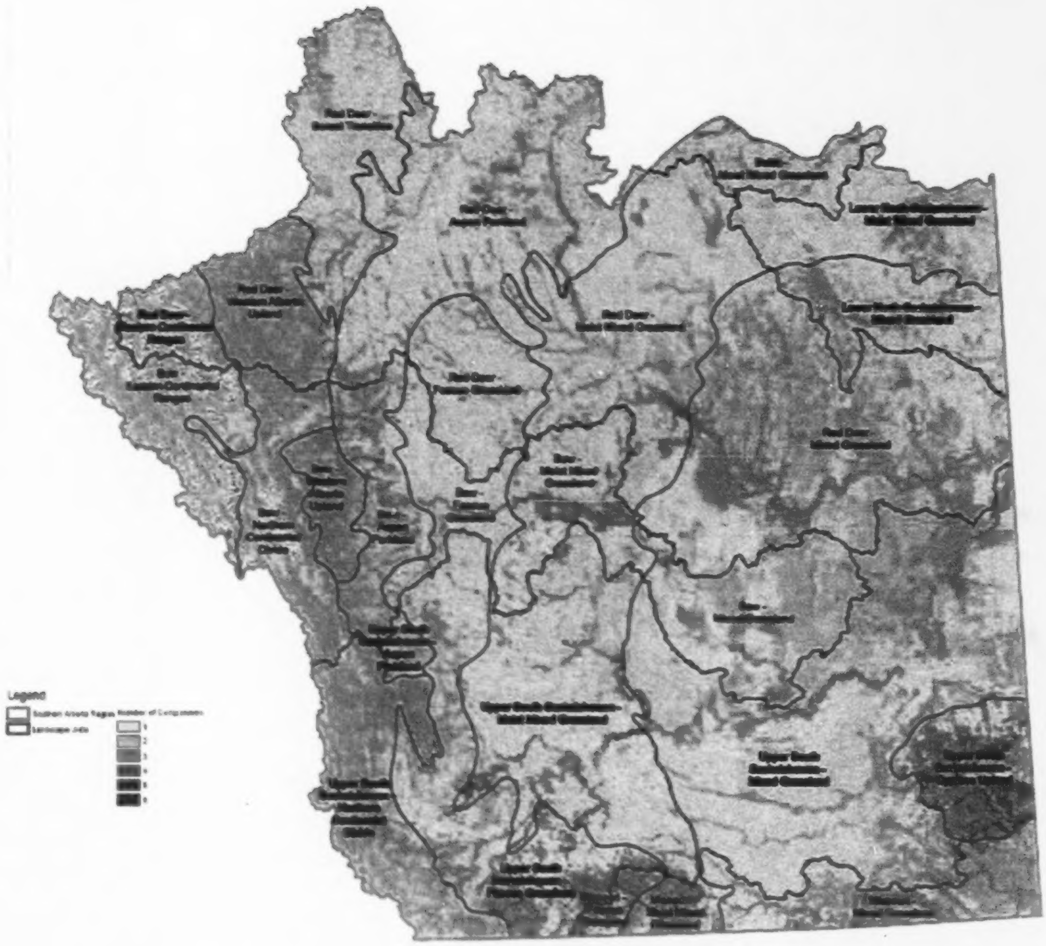


Figure 6.1. Aggregated scoring of ecological infrastructure components.

To identify the areas of coincidence between ecological infrastructure and a spatial representation of ecosystem services in the region, the binary map of ecological infrastructure as well as each individual ecological infrastructure component was analyzed against a map representing the mean value of the importance of an asset to all ecosystem services. These values ranged from '-2' (the asset has a strong negative effect on the provision of ecosystem services) to '2' (the asset has a strong positive effect on the provision of ecosystem services). For the coincidence of analyses, areas considered high in terms of ecosystem service provision were defined as those areas with an average value > '1': the top 25% of mapped values.

The results of crossing the ecological infrastructure with areas of high importance to ecosystem services showed high correlation and some interesting results (Figure 6.2; Table 6.2).

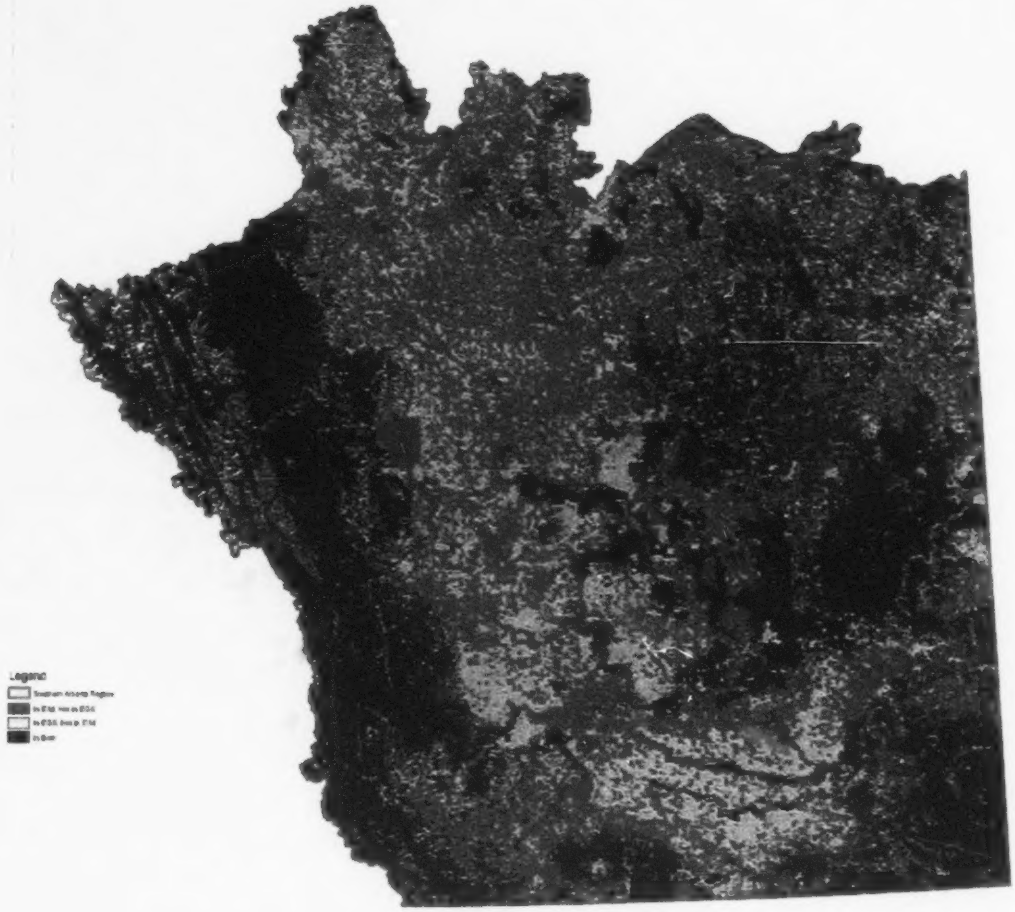
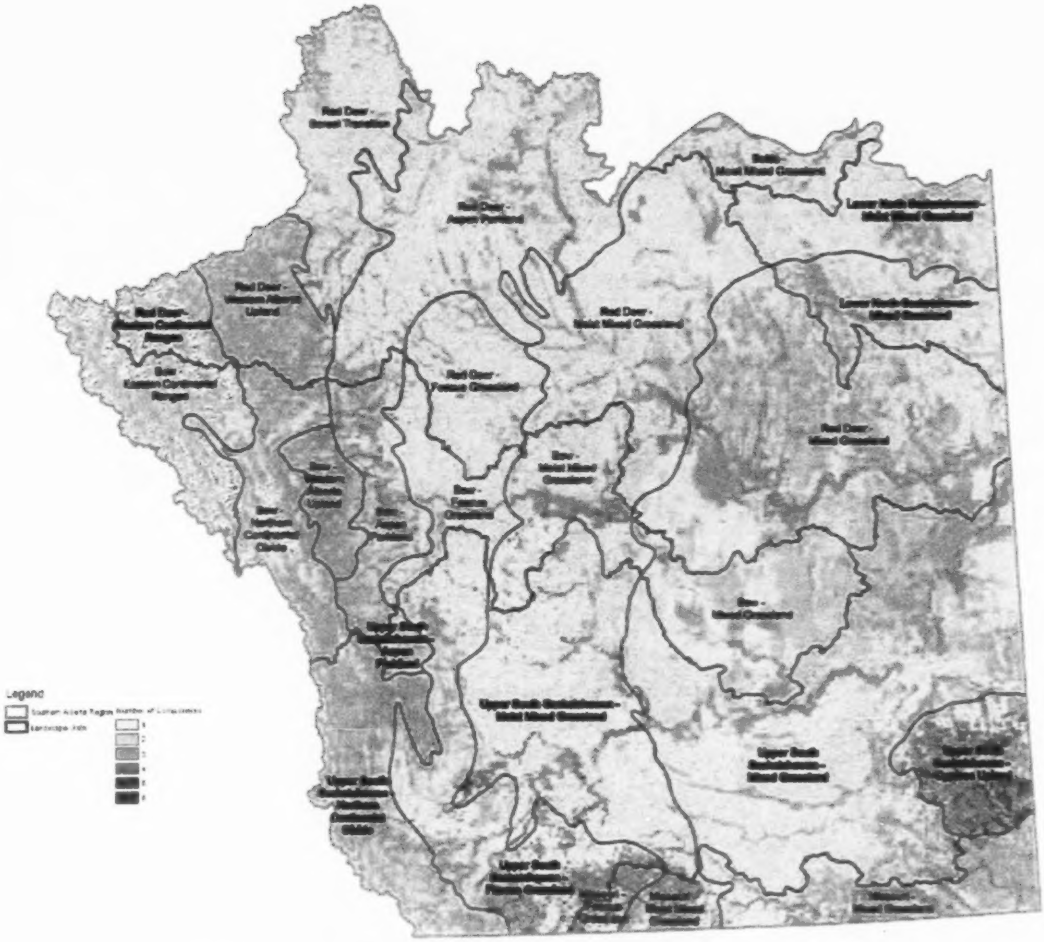


Figure 6.2. Coincidence of analysis between ecological infrastructure mapping (EIM) and areas of high value to ecosystem services (EGS).



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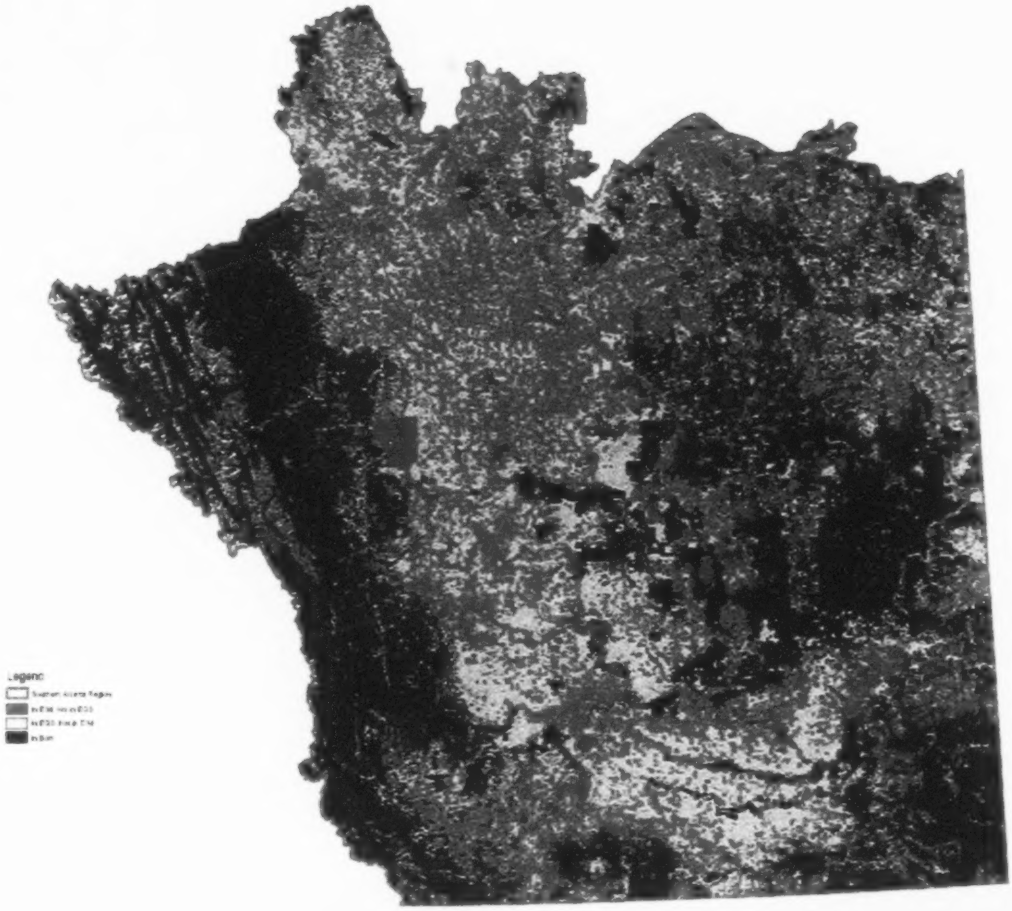

Figure 6.2. Coincidence of analysis between ecological infrastructure mapping (EIM) and areas of high value to ecosystem services (EGS).

Table 6.2. Areas of coincidence and non-coincidence between ecological infrastructure components and areas of high ecosystem service provision.

	In Ecological Infrastructure Only		In Areas of High Ecosystem Service Provision Only		Areas of Coincidence	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Ecological Infrastructure (All)	4 209 955	75.2	25 172	0.4	5 573 190	99.6
Stream Corridors	1 069 686	19.1	4 326 711	77.3	1 270 796	22.7
Natural Patches (Large Patches & Stepping Stones)	1 964 605	35.1	268 305	4.8	5 330 049	95.2
Large Patches	1 490 674	26.6	1 449 529	25.9	4 148 953	74.1
Stepping Stones	473 999	8.5	4 414 671	78.9	1 183 683	21.1
Waterbody Complexes	167 220	3.0	5 385 775	96.2	212 381	3.8
High Species Richness Potential	1 274 118	22.8	1 572 507	28.1	4 025 855	71.9
Alluvial Soils	837 180	15.0	5 119 000	91.4	479 362	8.6
Low Percentage Cover Types	1 964 168	35.1	3 928 302	70.2	1 669 417	29.8
High Species Richness Potential & Natural Patches (Large Patches & Stepping Stones)	2 262 072	40.4	189 786	3.4	5 408 568	96.6

The ecological infrastructure encompassed 99.6% of all areas identified as high ecosystem service provision. Natural patches alone, including both large patches and stepping stone complexes, included 95.2% of those areas. When combined with areas of high species richness potential, the percentage was increased to 96.6. Natural patches, large patches alone and high species richness potential were the components that gave the highest coincidence with areas of high ecosystem service provision. Of moderate value in predicting areas of high ecosystem services were stream corridors, stepping stones alone, and low percentage cover types. Other components of ecological infrastructure that had poor coincidence with mapped areas of high ecosystem services included alluvial soils and waterbody complexes. These components, and to some extent stream corridors, include other areas not considered as 'high' in terms of ecosystem service provision. The poor coincidence may be attributed to these analyses being unrelated (or indirectly related) to landcover type or asset, which was used to assign ecosystem service value. Alluvial soils may be overlain by any type of asset, including anthropogenic assets which have lower ecosystem service values. Similarly, waterbody complexes represent the zone of influence of waterbody ecology and are identified by buffering waterbodies. This buffer zone should ideally be in natural landcover in terms of a complete ecological

infrastructure, but in Southern Alberta these areas were often anthropogenic assets (e.g., agriculture) and had lower ecosystem service provision values.

In terms of the condition of ecosystem services, those areas of high service provision that are coincident with ecological infrastructure are most likely to be in good condition through landscape connections and within large natural patches that promote functioning ecological processes. Those areas currently providing ecosystem services that are outside the ecological infrastructure (e.g., unconnected or small patches) may be priority areas for enhancing ecosystem service condition by promoting connections or establishing natural buffers between stream corridors and waterbodies.

7.0 Recommendations for Future Application

This study indicates that a relatively limited set of ecological infrastructure components related to landscape pattern can have a significant and positive impact in terms capturing most ecosystem goods and services. A simple analysis using the large patches model, stepping stones model and species richness model may be used over any region or subset of this region if the goal is to identify areas of highest ecosystem service provision. If the goal is to identify areas for potential restoration or establishment of natural connections, other models such as alluvial soils, stream corridors, or waterbody complexes may be used. These are areas of potentially high ecosystem service provision if restored to natural assets. Other land uses, including anthropogenic assets, may be more appropriate outside the ecological infrastructure.

On a regional scale, the additive map of ecological infrastructure highlights those areas of importance where the provision of ecological services should be high and in good condition (see Section 6.0, Figure 6.1). While all components of ecological infrastructure are important, those areas incorporating a greater number of overlapping components may be prioritized in terms of land use planning for natural areas and conservation.

Each component of ecological infrastructure can be mapped on smaller scales, depending on the desired objectives. On scales of a single landscape unit or watershed, for example, 10 m to 100 m buffers around individual wetlands might be identified (e.g., Section 4.3). Finer-scale analyses can identify smaller-scale ecological processes such as microclimate regulation and local pollination or biological control which may be extremely valuable to that location. Full landform analysis, including identification of ridge features through the TPI model, also becomes applicable at finer scales.

Another method to identify critical landscape patterns and habitat at a finer scale is to model the habitat requirements of a suite of species chosen to represent specific ecological processes. This type of habitat suitability index (HSI) modelling may be valuable at the scale of natural subregions, for example. Species chosen for HSI modelling should have ranges that overlap the entire study area and should represent different habitat types, be sensitive to change at a variety of scales, and be representative of ecological processes (e.g., long range dispersal, pollination) (O2 Planning + Design et al. 2007).

At finer scales, site-level assessments could be used to evaluate asset condition in future analyses. For example, a grassland vegetation inventory is a useful tool to measure the condition of a single patch of an asset such as native grassland. These tools could be used to prioritize areas of potentially high ecosystem services and good landscape-level condition and for local restoration.

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Appendix A – Data Sources

Data sources for the project included Alberta Environment (AENV), Canadian Forest Service (CFS), Alberta Sustainable Resource Development (ASRD), Alberta Agriculture and Rural Development (AARD) and O2 Planning + Design Inc. (O2; processed data). Data and processing are described in Table A.1.

Table A.1. Data sources, data and general processing.

Data Source	Data and Processing
GOA	Integrated Southern Alberta Inventories (Forest and Grassland) Digital Elevation Model (DEM) Data • DEM tiles were mosaicked using ArcGIS 9.2 Data Management Tools → Raster → Mosaic command o Parameters: ▪ Mosaic Method: BLEND ▪ Mosaic Colormap Mode: FIRST Digital hydrography (lines and polygons) for the study area CFS Canada Mosaic based on Landsat 7 Enhanced Thematic Mapper (ETM) data from bands 7, 4, and 2 • Imagery is circa 1990 and was used for broad-scale cartographic presentation and visual verification of landscape units (LUs) • Imagery was clipped to the area surrounding the integrated southern Alberta inventories dataset and re-projected to NAD 83 TM-115 with a 25-m cell size Alberta Natural Subregions (NSR) • Clipped to study area boundary and reprojected to NAD 83 TM-115 • Data acquired from SRD website February 10th, 2008. Data currency is June 2, 2005 and positional accuracy is at most +/- 500 metres throughout the study area. • Used for delineation of LMUs Alberta AGRASID soils data
AAFC	National Agri-Environmental Health Analysis and Reporting Program (NAHARP) species range maps by CANSIS soil polygon converted to file geodatabase

Data Source	Data and Processing
O2	Percent slope • Derived from processing of DEM using ArcGIS 9.2 Spatial Analyst → Surface → Slope command • Values higher than 100 were classified as 100 and a 100 m radius focal mean was applied to smooth anomalous stepped areas • Accuracy is +/- 100 m Hillshade • Created for cartographic output using ArcGIS 9.2 Spatial Analyst → Surface → Hillshade command • A 100 m radius focal mean was applied to smooth anomalous stepped areas • Not used for analysis so accuracy is not applicable

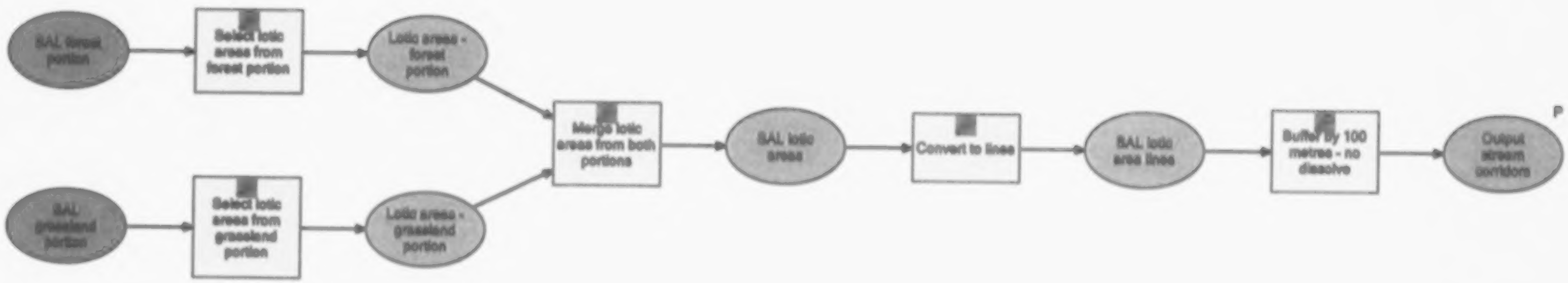
Appendix B – Project Analysis Tables

Table B.1. Project analysis table comparing features of resource survey methods to components of ecological infrastructure mapping.

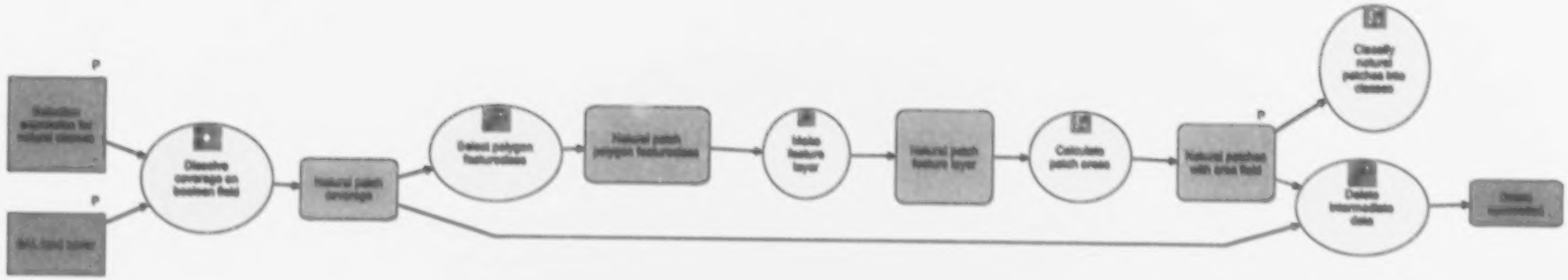
Ecological Infrastructure				
Resource Survey Features	**Components of Ecological Infrastructure Mapping**	**Data**	**Current Analysis**	**Potential Future Analysis**
Landform	Areas of unique land cover	DEM	Map identifying major ridge topography	Other landforms more appropriate at sub-regional/local scale
Drainage network	Stream corridors	integrated southern Alberta inventories lotic	Map identifying streams buffered to 100 m on each side	
	Waterbody complexes	integrated southern Alberta inventories lentic	Map identifying permanent and intermittent water body complexes	
		AltaLIS intermittent waterbodies		
Aquifer areas	Alluvial soils	AgraSID	Map identifying alluvial soils in grassland areas	Alluvial soils identification in forested areas when data becomes available
Vegetation cover	Large natural patches	integrated southern Alberta inventories	Map identifying large patches of native vegetation that meet certain size threshold criteria for varying species groups	
	Stepping stones	integrated southern Alberta inventories	Map identifying functionally connected patches of native vegetation	

Ecological Infrastructure				
Resource Survey Features	**Components of Ecological Infrastructure Mapping**	**Data**	**Current Analysis**	**Potential Future Analysis**
Wildlife habitat (in addition, see below)	Large natural patches	integrated southern Alberta inventories	Map identifying large patches of native vegetation that meet certain size threshold criteria (see Vegetation Cover)	
	Stepping stones	integrated southern Alberta inventories	Map identifying functionally connected patches of native vegetation (see Vegetation Cover)	
Bird and other wildlife distribution	Species richness potential mapping	integrated southern Alberta inventories	Map identifying approximate number of species per land cover polygon	

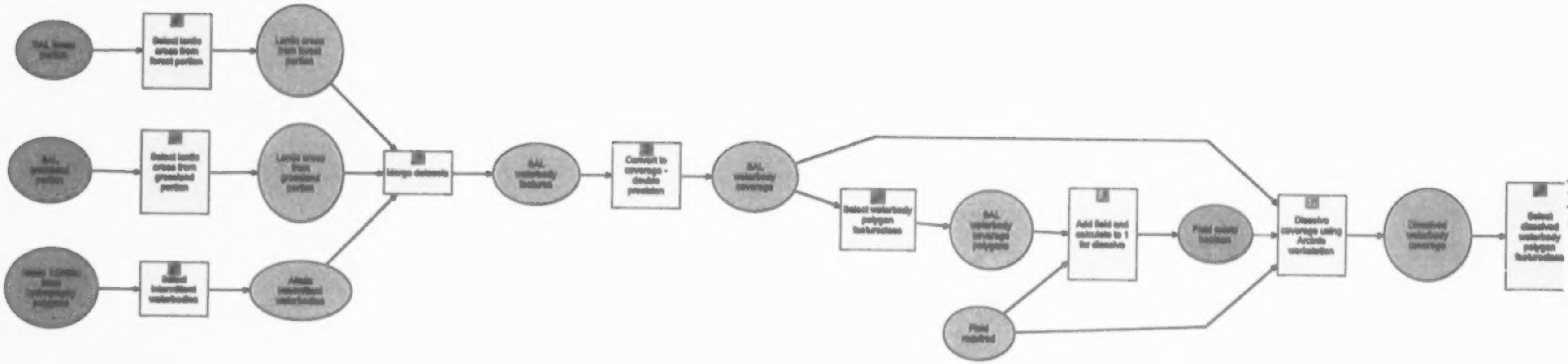
Appendix C – ArcGIS 9.2 Flowcharts



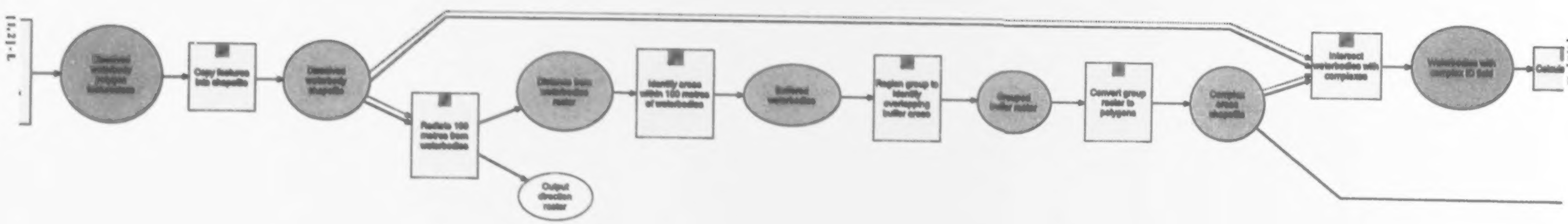
Identify Lotic Corridors



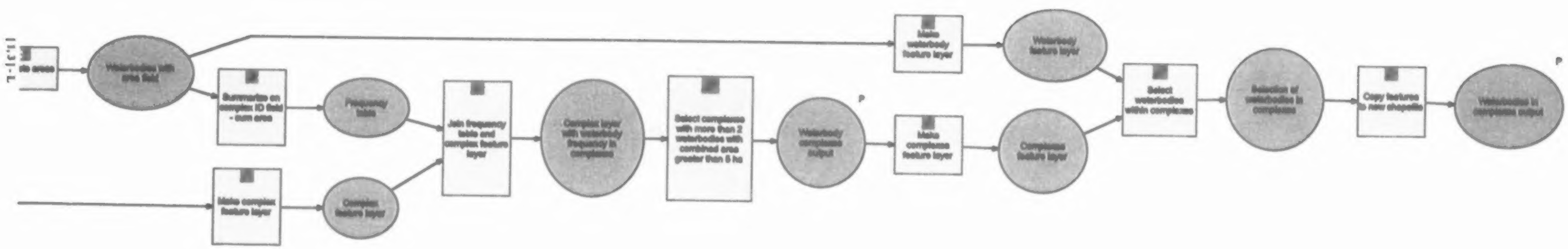
Calculate Natural Patch Sizes - Agricultural Portion



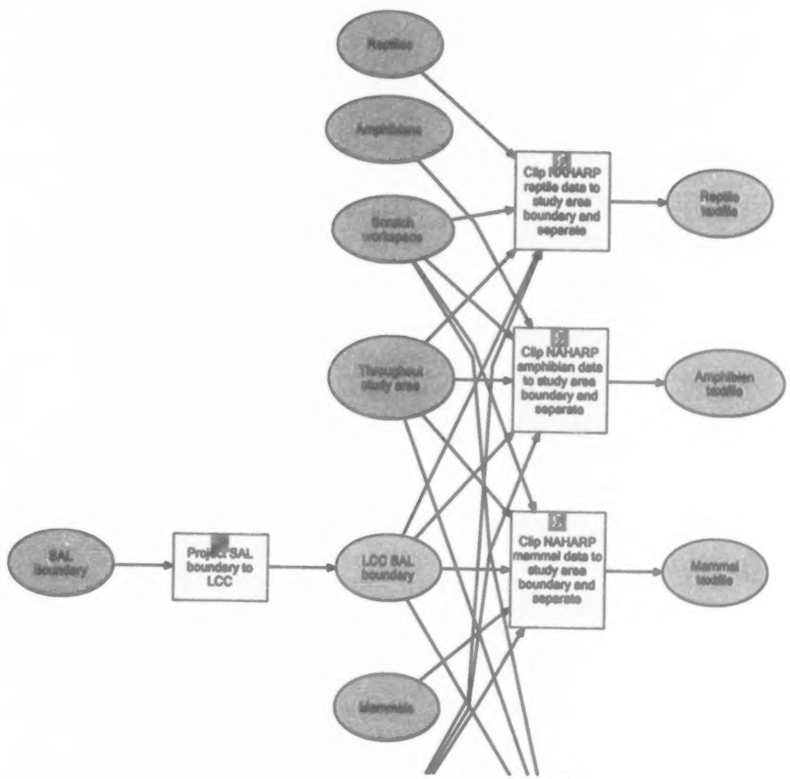
Identify Waterbody Complexes



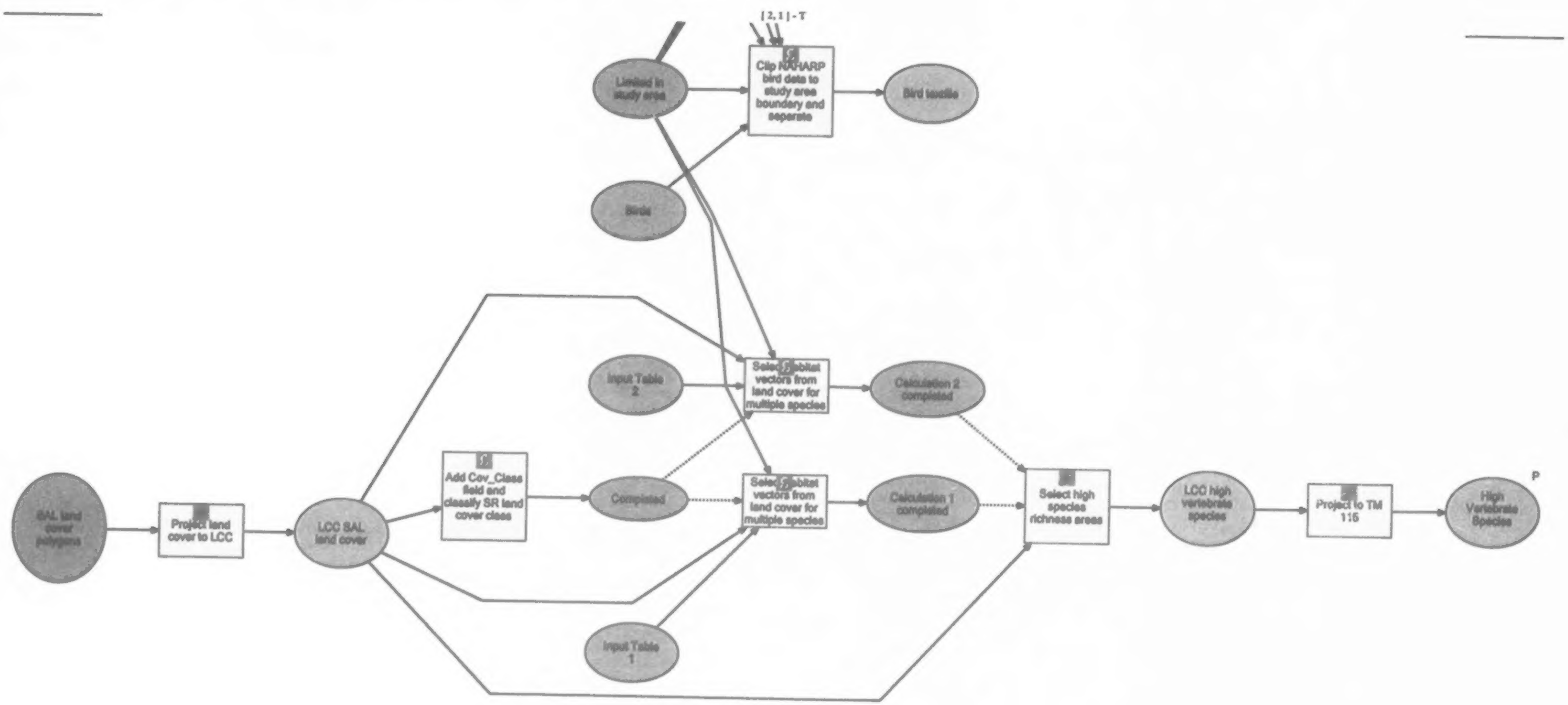
Identify Waterbody Complexes



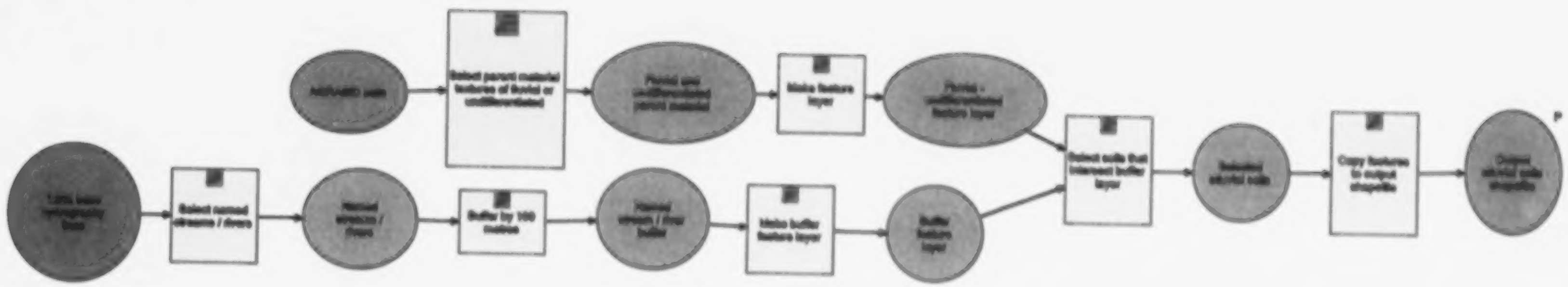
Identify Waterbody Complexes


Reptiles
Amphibians
Scratch workspace
Throughout study area
SAL boundary
Project SAL boundary to LCC
LCC SAL boundary
Mammals
Clip NAHARP reptile data to study area boundary and separate
Clip NAHARP amphibian data to study area boundary and separate
Clip NAHARP mammal data to study area boundary and separate
Reptile textfile
Amphibian textfile
Mammal textfile

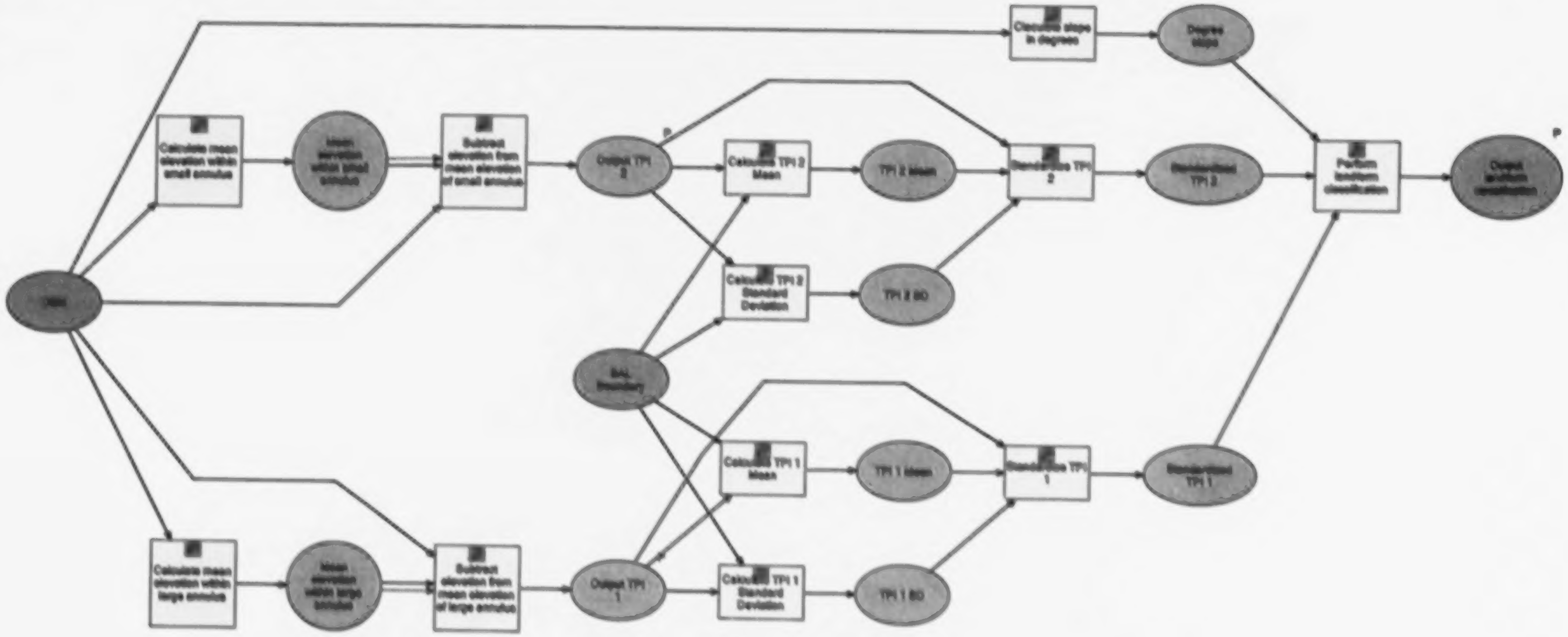
[1.1]-B



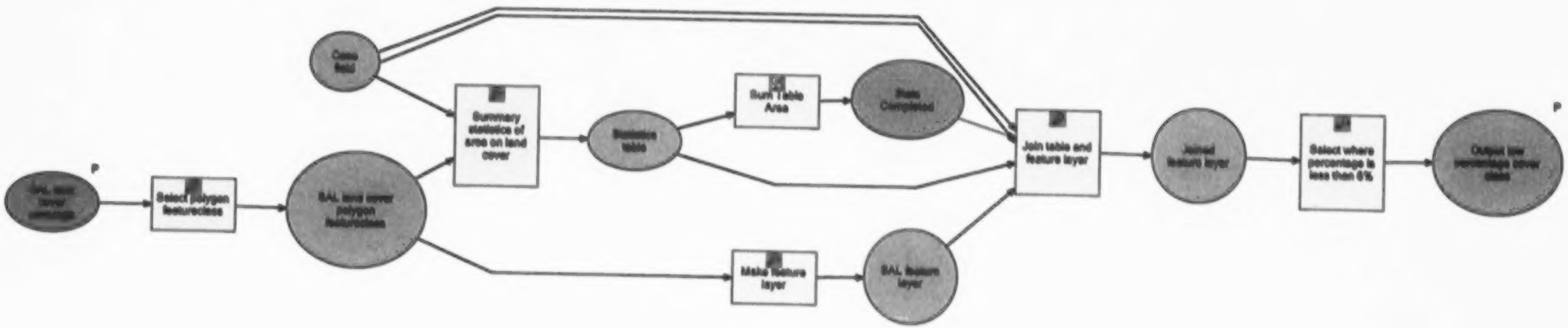
Identify Areas of High Species Richness



Identify Alluvial Soils



TPI Landform Classification



Identify Rare Cover Classes - Forest Portion

Appendix D – Vertebrate Species of Southern Alberta

Amphibians

Species Name	Range in Hectares
Ambystoma macrodactylum	3338862
Ambystoma tigrinum	10825481
Bufo boreas	2641185
Bufo cognatus	2497959
Bufo hemiophrys	11538642
Pseudacris maculata	12225232
Pseudacris regilla	61842
Pseudacris triseriata	578244
Rana luteiventris	1946729
Rana pipiens	7877056
Rana sylvatica update	13473118
Spea bombifrons	7777011

Birds

Species Name	Range in Hectares
Accipiter cooperii	9713495
Accipiter gentilis	13722076
Accipiter striatus	8084461
Actitis macularia	13722076
Aechmophorus occidentalis	13722076
Aegolius acadicus	13722076
Aegolius funereus	3570032
Agelaius phoeniceus	13722076
Aix sponsa	1957620
Ammodramus bairdii	11332096
Ammodramus leconteii	11319077
Ammodramus nelsoni	4985161
Ammodramus savannarum	7368906
Anas acuta	13722076
Anas americana	13722076
Anas clypeata	13722076
Anas crecca	13722076
Anas cyanoptera	10504362
Anas discors	13722076
Anas platyrhynchos	13722076
Anas strepera	12923781
Anser albifrons	9775117
Anthus rubescens	13722076
Anthus spragueii	13140657
Aquila chrysaetos	13722076
Archilochus colubris	8964772
Ardea herodias	13488367
Asio flammeus	13722076
Asio otus	13722076
Athene cunicularia	9951446
Aythya affinis	13722076
Aythya americana	12681689

Aythya collaris	13722076
Aythya marila	3934712
Aythya valisineria	10147371
Bartramia longicauda	11672592
Bombycilla cedrorum	13722076
Bombycilla garrulus	13722076
Bonasa umbellus	10637263
Botaurus lentiginosus	13722076
Branta canadensis	13722076
Bubo scandiacus	13609574
Bubo virginianus	13722076
Bucephala albeola	13722076
Bucephala clangula	13722076
Bucephala islandica	1815210
Buteo jamaicensis	13722076
Buteo lagopus	13722076
Buteo platypterus	5839352
Buteo regalis	6435533
Buteo swainsoni	13722076
Calamospiza melanocorys	11317011
Calcarius lapponicus	13722076
Calcarius mccownii	10265268
Calcarius ornatus	10739885
Calcarius pictus	2463916
Calidris alpina	10647222
Calidris himantopus	2278372
Calidris melanotos	11878104
Calidris minutilla	13722076
Calidris pusilla	13722076
Callypte anna	366108
Carduelis flammea	13722076
Carduelis hornemanni	13722076
Carduelis pinus	13722076
Carduelis tristis	13691708
Carpodacus cassinii	1734442
Carpodacus purpureus	4539959
Cathartes aura	11336413
Catharus fuscescens	13722076
Catharus guttatus	13722076
Catharus minimus	200009
Catharus ustulatus	13722076
Catoptrophorus semipalmatus	12961376
Centrocercus urophasianus	1703012
Certhia americana	13722076
Ceryle alcyon	13722076
Chaetura vauxi	5851114
Charadrius melodus	6987942
Charadrius semipalmatus	13722076
Charadrius vociferus	13722076
Chen caerulescens	12869351
Chen rossii	4289167
Chlidonias niger	13624954
Chondestes grammacus	7454144
Chordeiles minor	13722076
Cinclus mexicanus	4966296
Circus cyaneus	13722076
Cistothorus palustris	11119744
Coccothraustes vespertinus	13722076
Coccyzus erythropthalmus	9068787
Colaptes auratus	13722076
Columba livia	11608173
Contopus cooperi	13721479
Contopus sordidulus	13722076
Corvus brachyrhynchos	13722076
Corvus corax	2752446
Coturnicops noveboracensis	10538219
Cyanocitta cristata	11922512
Cyanocitta stelleri	3607665
Cygnus buccinator	5125555
Cygnus columbianus	13722076
Cypseloides niger	61845
Dendragapus obscurus	1885218
Dendroica coronata	13722076
Dendroica magnolia	2903080
Dendroica palmarum	1023306
Dendroica petechia	13722076
Dendroica striata	13722076
Dendroica tigrina	536577
Dendroica townsendi	1958805
Dolichonyx oryzivorus	8054967
Dryocopus pileatus	3037870
Dumetella carolinensis	13719380
Empidonax alnorum	6882511
Empidonax difficilis	15822
Empidonax flaviventris	7505824
Empidonax hammondii	2071891
Empidonax minimus	13722076
Empidonax oberholseri	4243379

Empidonax occidentalis	1565255	*Mergus serrator*	13722076
Empidonax traillii	12908540	*Mimus polyglottos*	1887918
Eremophila alpestris	13722076	*Miniotilta varia*	5109563
Euphagus carolinus	13721885	*Molothrus ater*	13722076
Euphagus cyanocephalus	13534785	*Myadestes townsendi*	9629305
Falcipennis canadensis	3086810	*Nucifraga columbiana*	6922997
Falco columbarius	13722076	*Numenius americanus*	10572292
Falco mexicanus	13540956	*Nycticorax nycticorax*	4624272
Falco peregrinus	5731214	*Oporornis agilis*	1247915
Falco rusticolus	13722076	*Oporornis philadelphia*	60927
Falco sparverius	13722076	*Oporornis tolmiei*	3173024
Fulica americana	13722076	*Oxyura jamaicensis*	11457450
Gallinago delicata	13722076	*Pandion haliaetus*	13722076
Gavia immer	13722076	*Passer domesticus*	13722076
Geothylpis trichas	13722076	*Passerculus sandwichensis*	13722076
Glaucidum gnoma	4339805	*Passerella iliaca*	13722076
Grus canadensis	13722076	*Passerina amoena*	3373571
Haliaeetus leucocephalus	8959440	*Pelecanus erythrorhynchos*	13722076
Hirundo rustica	13722076	*Perdix perdix*	11977134
Histrionicus histrionicus	3274849	*Perisoreus canadensis*	179531
Icteria virens	7773880	*Petrochelidon pyrrhonota*	13722076
Icterus bullockii	2355238	*Phalacrocorax auritus*	13623042
Icterus galbula	13080096	*Phalaenoptilus nuttallii*	999734
Ixoreus naevius	3170762	*Phalaropus tricolor*	13722076
Junco hyemalis	13722076	*Phasianus colchicus*	13248232
Lagopus leucura	2824734	*Pheucticus ludovicianus*	12808060
Lanius excubitor	13722076	*Pheucticus melanocephalus*	9828766
Lanius ludovicianus	13138588	*Pica hudsonia*	13722076
Larus argentatus	13722076	*Picoides arcticus*	7206233
Larus californicus	13722076	*Picoides dorsalis*	3375596
Larus delawarensis	13722076	*Picoides pubescens*	13722076
Larus philadelphia	13722076	*Picoides villosus*	13722076
Larus pipixcan	13722076	*Pinicola enucleator*	13722076
Leucosticte tephrocotis	12153438	*Pipilo maculatus*	13289411
Limnodromus scolopaceus	13722076	*Piranga ludoviciana*	13722076
Limosa fedoa	12410597	*Plectrophenax nivalis*	13722076
Lophodytes cucullatus	6167759	*Podiceps auritus*	13722076
Loxia curvirostra	13722076	*Podiceps grisegena*	8601792
Loxia leucoptera	13722076	*Podiceps nigricollis*	13722076
Melanerpes lewis	2682796	*Podilymbus podiceps*	13000545
Melanitta fusca	10392338	*Poecile atricapilla*	13722076
Melospiza georgiana	1706317	*Poecile gambeli*	5357113
Melospiza lincolnii	13722076	*Poecile hudsonica*	4137239
Melospiza melodia	13722076	*Poecile rufescens*	1887689
Mergus merganser	13722076	*Pooecetes gramineus*	13722076

Porzana carolina	13722076
Progne subis	620136
Quiscalus quiscula	12136945
Rallus limicola	9700021
Recurvirostra americana	11733902
Regulus calendula	8580231
Regulus satrapa	6578315
Riparia riparia	13722076
Salpinctes obsoletus	7335452
Sayornis phoebe	2961456
Sayornis saya	11351403
Seiurus aurocapillus	2856726
Seiurus novemboracensis	13722076
Selasphorus rufus	3656748
Setophaga rutilla	2515772
Sialia currucoides	13722076
Sialia mexicana	203278
Sitta canadensis	13722076
Sitta carolinensis	12994317
Sphyrapicus nuchalis	11528540
Sphyrapicus varius	2636341
Spizella arborea	13722076
Spizella breweri	9995126
Spizella pallida	13722076
Spizella passerina	13722076
Stelgidopteryx serripennis	13722076
Stellula caliope	2824307
Sterna caspia	1145615
Sterna fosteri	11184873
Sterna hirundo	13722076
strix nebulosa	25641
Strix varia	3883006
Sturnella neglecta	13540597
Sturnus vulgaris	13722076
Surnia ulula	6666514
Tachycineta bicolor	13722076
Tachycineta thalassina	11590835
Toxostoma rufum	13364956
Tringa flavipes	13722076
Tringa melanoleuca	13722076
Tringa solitaria	12003905
Troglodytes aedon	13295698
Troglodytes troglodytes	1460735
Turdus migratorius	13722076
Tympanuchus phasianellus	13722076
Tyrannus tyrannus	13722076
Tyrannus verticalis	11703077
Vermivora celata	13722076
Vermivora peregrina	12700643
Vermivora ruficapilla	372194
Vireo cassinii	1126984
Vireo gilvus	13722076
Vireo olivaceus	13722076
Vireo philadelphicus	10512014
Vireo solitarius	3852508
Wilsonia canadensis	108194
Wilsonia pusilla	13722076
Xanthocephalus xanthocephalus	13722076
Zenaida macroura	13691998
Zonotrichia albicollis	13721966
Zonotrichia atricapilla	743869
Zonotrichia leucophrys	13722076
Zonotrichia querula	11787131

Mammals

Species Name	Range in Hectares
Alces alces	5274264
Canis latrans	13722076
Canis lupus	13610350
Castor canadensis	13722076
Cervus elaphus	5814491
Clethrionomys gapperi	13722076
Dipodomys bursarius	3202473
Eptesicus fucus	13722076
Erthizon dorsatum	13722076
Euderma maculatum	434177
Glaucomys sabrinus	7935019
Lasionycteris noctivagans	13722076
Lasiurus blossevillii	3952359
Lasiurus borealis	13722076
Lasiurus cinereus	13722076
Lemmiscus curtatus	11339510
Lepus americanus	9365103
Lepus townsendii	13509122
Lontra canadensis	5693844
Lynx canadensis	8434258
Lynx rufus	7752476
Marmota caligata	3437046
Marmota flaviventris	2859619
Marmota monax	2813157
Martes americana	2669144
Martes pennanti	1428092
Mephitis mephitis	13722076
Microtus longicaudus	8311290
Microtus ochrogaster	10029
Microtus pennysylvanicus	13722076
Microtus richardsoni	2582144
Mustela erminea	9147394
Mustela frenata	13722076
Mustela nivalis	13473118
Mustela vison	13722076
Myotis californicus	427
Myotis ciliolabrum	8652160
Myotis evotis	13046900
Myotis lucifugus	13722076
Myotis septentrionalis	260648
Myotis volans	12936820
Myotis yumanensis	1073964
Neotama cinerea	5198790
Neotamias minimus	11029397
Neotamias ruficaudus	488024
Ochotona princeps	3329513
Odocoileus hemionus	13722076
Odocoileus virginianus	13722076
Ondatra zibethicus	13722076
Onychomys leucogaster	10269136
Oreamnos americanus	5876828
Ovis canadensis	9762133
Perognathus fasciatus	3126613
Peromyscus leucopus	2065464
Peromyscus maniculatus	13722076
Phenacomys ungava	3777383
Procyon lotor	13219703
Puma concolor	11932388
Reithrodontomys megalotis	3553682
Sorex arcticus	90194
Sorex cinereus	13722076
Sorex hoyi	5967865
Sorex monticolus	6233651
Sorex preblei	17195
Sorex vagrans	671009
Spermophilus columbianus	3120267
Spermophilus franklinii	1118746
Spermophilus lateralis	3444541
Spermophilus richardsonii	13270148
Spermophilus tridecemlineatus	11943703
Sylvilagus nuttallii	12155606
Synaptomys borealis	5236969
Tamiasciurus hudsonicus	412
Taxidea taxus	13217645
Thomomys talpoides	12064247
Ursus arctos	10731928
Ursus americanus	2374668

Vulpes velox	11693142	*Zapus princeps*	13722076
Vulpes vulpes	13722076		
Zapus hudsonius	5587922		

Reptiles

Species Name	Range in Hectares	Species Name	Range in Hectares
Charina bottae	887933	*Pituophis catenifer*	13028213
Chrysemys picta	2994933	*Thamnophis elegans*	13722076
Crotalus viridis	6616467	*Thamnophis radix*	12129301
Heterodon nasicus	5410479	*Thamnophis sirtalis*	8132907
Phrynosoma hernandesi	3843930		